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PERFORMANCE OF FEASIBILITY STUDIES AND SYSTEM DESIGN ANALYSES AT SIX POTENTIAL MICROHYDRO SITES

Prepared for

MONTANA DEPARTMENT of NATURAL RESOURCES and CONSERVATION

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PERFORMANCE OF FEASIBILITY STUDIES AND SYSTEM DESIGN ANALYSES AT SIX POTENTIAL MICROHYDRO SITES

Prepared by

Richard Wrench
295 Highland Drive
Kalispell, MT 59901

January, 1982

Prepared for

Montana Department of Natural Resources and Conservation
32 South Ewing, Helena, Montana 59620
Renewable Energy and Conservation Program
Grant Agreement Number 650-810

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feet down the mountain, under the State highway, and run a generator. Power thus produced would be used to heat the home in the winter, power the usual electrical load, & provide irrigation in the summer. In the proposal it was stated that DNRC's staff had measured the head & water flow. The power calculations indicated a maximum of 3 kilowatts of useable power could be generated. Due to the vagueness of site description provided by Barnard and their non-availability to assist only the section could be located, and not the exact site. It was therefore not possible to survey the site. Judgemental factors indicated that due to the very small volume of water, the 1,200 foot distance, the fact that the electrical power lines ran down the highway, very close to any point in the section, the estimated costs of $41,350 to develop the project compared to a couple hundred dollars maximum to hook up to the existing electrical power, that the project would not be feasible. The small potential of the site would not be capable of providing even a fraction of the normal electrical power requirements of a home, let alone heat it.

Due to the lack of cooperation from the grantee and the above factors, it was determined this site was not feasible. After the study was completed and submitted, I was contacted by Mr. Barnard. I was read the riot act, learned a few new verbal superfluous words , and had personal cause to suspect the motives behind the grant application. The project was not recommended for development.

Site # 5. Six Shooter Ranch Co., Big Timber Montana

The Six Shooter Ranch Co., located approximately 8 miles north of Big Timber, requested DNRC study a canal & falls flowing through the ranch to determine its hydroelectric potential. Water flows through the canal 5 months out of the year and is eventually consumed by the ranchers along its route. The site had approximately 33 C.F.S. water flow and a vertical drop over the falls of 37½ feet. Primary electrical power is within 600 feet of the site. A conservative estimate would have the site producing approximately 65 kilowatts of power 24 hours each day for the time period the water is available. This amount of power is far in excess of the ranch needs. Several design options were analyzed, ranging from selling the power to the utility company on a 5 month basis, devising a means of year around water flow to sell on a 12 months basis, to generating power for ranch consumption only.

The site is an exceptionally ideal one from a technical & practical consideration consideration. Unfortunately the cost to develop the site makes it extremely non-cost-effective. The ranch owners are obviously very capable people. It was suggested that it would be possible for them to devise ways to overcome some of the problems identified. These people have historically found ingenuous, low cost solutions to proplems. They were provided a statement of what problems they face and the associated costs.

If they can devise a means of solving some of their cost problems, then this site could become quite feasible. The two fundamental problems were providing water flow for the entire year and the high cost of the generating equipment required. It is recommended this project be simply placed on a back burner pending well thought out proposals from the ranch personnel. Should they request assistance it should be favorably considered.

Site # 6. City of Bozeman

Mr. Russ Heliker, Energy Planner for the City of Bozeman, requested DNRC study Bozeman Creek to determine its hydroelectric generating potential. The City desired to use the power to light its downtown buildings, sell excess power to the utility company, and utilize the site as a public demonstration of renewable energy at work.

Five potential sites were identified. An engineering study was conducted at each. For each site, the net useable amount of electrical power was determined, the cost to construct the facility estimated, and the revenue the City might expect was calculated. The following sites were studied.

1. The diversion dam at the mouth of Bozeman Canyon.
2. The presedimentation settling basins.
3. The municipal water reservoir.
4. Down town Bozeman, adjacent to the new library.
5. Along the railroad right of way to the City Park.

In each case the cost to develop the site was excessive when compared to the revenue it would produce. Uncontrolled flooding, very shallow land & legal problems also complicated each site. Unfortunately, none of the sites investigated were feasible.

In each of the above sites, the engineering report should be read if additional information is desired.

GENERAL METHODOLOGY USED

All proposals and available history of the project were read. The principals were contacted to learn first hand how they viewed their project. This established what they expected of the project in terms of time,cost, performance, etc. The site was visited. The width of the water way was measured, using a steel tape. Several measurements were taken and averaged. Next, the depth of the water was measured every few inches at the exact point where the width was measured. The flow of the water was measured by a stop watch measurement of the time required for a wooden float to pass a measured distance. The following formula was used to calculate flow. The width of the creek, in feet, times the depth of the creek, in feet, times the distance the float travels in one minute, time the constant 0.8, equals the cubic feet of flow per minute. Divided by 60, the flow, in cubic feet per second, is available.

Elevations were determined using a Keuffel & Esser, K & E, surveying transit & stadia rod, along with the steel tape. Stakes down the hill method was used.

Power calculations used the following formula.

$$\text{Power, in KW} = \frac{\text{cubic feet per second x head in feet}}{11.8}$$

The no loss power was calculated first. This power was then adjusted as a function of (1) Flow at low water, (2) Head loss due to penstock friction, (3) Turbine efficiency, (4) Generator efficiency, (5) Transformer losses, & (6) Transmission line losses. The result was net useable electrical power.

Next, the entire project was costed. It was necessary to conduct extensive design analyses for each site inorder to be able to construct an on paper baseline system. In fact, most of the system design analyses was required for eachsite. The cost was that quoted by those companies currently in the business of selling the hardware required. In some cases it was assumed the individual grantee would be capable of doing much of the work himself. The material costs were identified. The labor costs must be locally bid in some cases.

The cost to benefit analyses, which really becomes the true measure of project feasibility, was done on a parametric basis. This was necessary at the price the utility companies will pay has not been determined. The federal law stated the power generated must be purchased. The price paid is still undefined. Feasibility, to a large extent hinges on the eventual price.

When all the facts were available, they were presented, informally to the Energy Division, where each project was discussed. A formal engineering report was prepared for each project. The orgionals were sent to Jeannie Thurston, at the Energy Division, and a copy to the principals.

PROJECT COSTS

The orgional grant agreement was for $8,500 for the purpose of four sites. The agreement was amended September 11, 1981, increasing the amount to $10,050. At that time two additional sites were added. The orgional contract specified the following costs.

Salaries & benefits:	$7,432.00
Supplies	148.00
Communications	300.00
Travel	620.00
Total	$8,500.00

The breakdown of costs appears to have followed very closely the authorized budget, at approximately $2,000 per site. The amended contract was for two additional sites, at a budget of $2,000 each. The itemized expenses for the first payment request was sent to the Bureau. The copy was lost or misplaced, so the Bureau will have to provide a breakdown on the initial payment request of $2,550.00. The second payment request was submitted July 21, 1981 and was itemized as follows.

Salaries & expenses		$3,061.00
Operating expenses		61.00
Communications		123.00
Travel		255.00
	Total	$3,500.00

The third payment request was submitted December 2, 1981, and was itemized as follows.

Salaries & expenses	$3,276.00
Operating expenses- supplies	249.00
Operating expenses-communications	160.00
Operating expenses-travel	315.00
	$4,000.00

Total costs billed to DNRC	$10,050.00

To put the costs in a more meaningfull perspective, consider the following. On the initial grant agreement, the four sites studied had the sum of $66,000 approved. The engineering study of these four sites cost $6,050. The $66,000 was saved for projects of merit by not funding non-feasible projects. When the City of Bozeman project was studied, five separate engineering studies were performed. In all, a total of ten sites were studied, for an average cost of approximately $1,000. each. A detailed engineering study for only $1,000. apiece is an unprecedented achievement.

EQUIPMENT MANUFACTURES

Appendix B of the contract deals with the manufacturers of hydroelectric generating equipment. DNRC desired knowledge of what is available. Initially, a total of 12 firms were identified for querry. Each of these firms were sent very detailed letters requesting a broad spectrum of performance, cost, services, availability, etc. Most of the initial 12 firms, plus others subsequently identified, turned out to be dead ends. I think the intent of practical knowledge is beat served by discussing the equipment manufactures that are or could be of value to the people of Montana, and not a retoric about those of negative value. In fact, one firm has been historically operating in Montana with a long history of poor responses. The following list is not meant to be all inclusive, rather those firms found to be of potential value.

Digetek Inc., 17455 68th Avenue N.E. #104, P.O. Box 468,
Kenmore, Washington 98028, Phone: (206) 485-6571

This firm offers computer controls for all facets of a typical hydroelectric facility. Examples of the items controled are: Turbine start/stop, Voltage raise/lower, Governor control raise/lower, Breakers Trip/close, & Gates raise/lower. This is a rather recent firm with good technical capability. They went after the segment of the market dealing in much larger generating facilities than the Bureau was interested in. However, they have indicated computer controls for the micro-hydro power will be forthcoming. Their price may be a bit high, but they have indicated they see the micro-hydro market as one they wish to go after. This firm should be followed as it progresses.

The James Leffel & Co., 426 East Street, Springfield, Ohio, 45501, phone: (513) 323-6431, Telex 205 419, Atten. Marketing engineering

The Leffel company is one of the oldest firms in the business of producing hydroelectric generating equipment, dating back to 1862. They almost went out of business. However, the Tampella Corporation took them over and they now appear to once again be a reliable supplier of quality equipment. If a reliable and quality turbine/generator system is desired, this firm should be considered. By writing to the above address, & enclosing all the salient technical parameters, they will select their best design, sending a complete quotation within a few weeks. For planning purposes, at least at this time, $1,000 for each kilowatt will be in the ball park of costing the turbine, generator, & control package. The quoted price has almost doubled in the last year, unfortunately.

Allis-Chalmers, Box 712, York, Pennsylvania 17405, Phone: (717) 792-3511, Atten. Howard A. Mayo, Jr. P.E., Manager, Product Promotion and Market development.

Allis-Chalmers specializes in hydroelectric systems above 25 KW, feeling outputs less than 25 KW are not economically practical for them to handle. They have two categories of equipment.

(1) The "Standarized Hydroelectric Generating Unit" is a horizontal shaft TUBE turbine designed for heads up to 65 feet, with capacities starting around 100 KW.

(2) A second line of packaged equipment ("Mini TUBE Turbines") has applications for sites with capacities between 25 and 1,000 KW, at heads up to a maximum of 40 feet.

Price, delivery, etc. all depend on specific site parameters. This firm has reliable & high quality equipment. The price & delivery time may preclude use by the small microhydro developer.

Small Hydroelectric systems & Equipment, 5141 Wickersham, Acme, Washington 98220, Phone: (206) 595-2312, Atten. Mr. William Kitching, Manager.

This firm is the number one supplier of packaged systems available to Northwest residents. Their system consists of a pelton wheel, belt driven generator/alternator, & requisite controls. Their current capacity is 10 to 50 KW. If this type system will satisfy the site requirements, it is certainly the lowest of all costs. They are a busy firm, selling their packaged systems all around the world. They also have available equipment for power grid intertie for selling power. It is not yet determined if the power companies will approve of the intertie equipment. With the pelton wheel, the basic approach is simply the higher the head the more the power.

Small Hydro-Electrics, Box 54, Silverton, B.C. VOG 2 BO, Canada
Phone: (604) 358-2406, Telex: 041-4150, Cable: Small Hydro, Nelson, atten. Craig P. Murphy, General Manager.

On May 15, 1981 this firm was appointed as an Authorized Representative of EQUIPEX Corporation for the United States and Canada. EQUIPEX Corporation is purported to be amongst the world's largest manufacturers of small hydroelectric generating equipment. They state they have nearly 100,000 units in operation in over 15 countries. They will quote on complete generating systems and hydro turbines with capacities to 12,000 kw.

Their descriptive literature looks good. It will be necessary to make a personal inspection to determine their quality. This is a firm that should be followed up if the opportunity presents itself.

Hydropower Consultants, Route 1, Box 169, Ronan, Montana 59864,
Phone: (406) 676-2141, atten. Mr. William H. Edelman.

This firm is in the business of designing and constructing complete hydroelectric generating facilities. They start at approximately 100 kilowatts and higher. Their normal operating method is to develop the site for the sale of power to the utility company. Once developed operation is turned over to others. This is a for profit operation. These people are demonstrated business & technical professionals.

At this writing the following suppliers have been identified. Their professionalism, capability, etc. is unknown. DNRC will be informed when the facts are known.

Energy Equipment Co., P.O. Box 10667, Bainbridge Island, Washington 98110, Phone: (206) 842-7338, attention Don Liupakka. This firm appears to supply all the hardware required for power generation systems, but not the turbines.

Energy Control Systems of Lake Oswego, 16841 SW Cortez Ct., Lake Oswego, Oregon 97034, Phone: (503) 636-8745, atten. Ron Adams.

Arnold J. Hanson, Hydroelectric Kilowatt Chaser, 12202-122nd st.
Puyallup, Washington 98373, Phone: (206) 848-0479

Susan Craft, Hydropower Northwest/Planning & Permitting, 600 1st Ave. West, Seattle, Washington 98104, 536 Pioneer Bldg. Phone: (206) 624-7456

Childs & Associates, Hydro Electric Systems & Consultants, P.O. Box 2217, Bellingham, Washington 98277, Phone: (206) 671-0107, attent. T.R. Childs.

The manufactures data has either been already delivered to Jeannie Thurston during prior visits or will be delivered personally January 28, 1982.

PERSONAL ASSESSMENT OF THE PROJECT

After studying a total of ten potential sites I feel this is one of the more outstanding programs orgionated by the Energy Division personnel. A detailed engineering study was conducted at each site for an average cost of $1,000 per site. The potential site developer is given a written report. Each site was visited. All the engineering measurements were taken, water volume, flow, head, topographical survey, elevations, etc. The need, use, electrical peak & average loading determined, capability of the individuals to complete the project, & all information necessary to determine if the project is feasible was collected. After an engineering study was complete a verbal and written report is prepared, detailing the methodology employed, the actual data gathered, conclusions drawn, recommendations, supporting rationale and probable costs established.

When complete, the potential site developer knows what to expect prior to any funds being committed. More importantly, the Energy Division has a technically defensible basis on which to base a decision to fund or not to fund a potential project. In the first four months of the contract, $66,000 was saved by not funding projects found to be non-feasible. Funds thus saved were made available to projects of merit. The money was not wasted and the government & its people were not subjected to criticism for funding projects found to be wasteful. Both the site developer & the Energy Division know what to expect in advance from the project. There should be no unexpected surprises.

The project was personally very rewarding and in some cases quite exciting. On one occasion we were stalked by a grizzly bear. On another we were driven up a 45 degree mountain in an all terrain vehicle with part of the wheels hanging in free space with a vertical drop straight down the mountain. I think it was good for all parties, not to mention the fact I was able to combine earning a living with excitement. I whole heartly urge this program be continued for the good of all.

ENGINEERING REPORT

To

Renewable Energy Bureau
Energy Division
Department of Natural Resources
and Conservation
32 South Ewing
Helena, Montana 59620

Prepared by:

Richard G. Wrench
295 Highland Drive
Kalispell, Montana 59901
Phone: 257-8575

Contract No. 650-810
Effective Date: 5/6/81
Contract Amount: $8,500.00

Nature of Contract

Performance of feasibility studies
and system design analyses at four
potential microhydro sites

Report on:

James Dick
P.O. Box 26
Cardwell, Montana 59721

"Hydroelectric System
Sole Source of Electricity
for Small Ranch"

Conclusion: THIS PROJECT IS NOT FEASIBLE & SHOULD NOT BE FUNDED
(see summary, page 13)

Submitted
Richard G. Wrench

Engineering report-James Dick, hydroelectric system

GENERAL COMMENTS

The site investigated is located approximately 15 miles southwest of Cardwell, Montana, in a very remote mountain setting. Cardwell is located approximately 35 miles east of Butte, just off I-90. The site is part of an old mining claim commonly called "Bear Gulch". Access is initially by paved county road, which becomes gravel and then an unmaintained dirt road. It is necessary to park in a meadow area 1½ to 2 miles from the property boundry. Just prior to the parking area is a bridge that is partially washed away and is unsafe to cross. Access to the site is by walking,horse, or some sort of an all terrain vehicle. Mr. Dick provided transportation to the site in a large 3/4 ton, 4-wheel drive vehicle. All four tires were of the wide variety and each chained. The trip was slow, exceptionally exciting, and not recommended for anyone with a heart condition. Access from the parking area to the property boundry is by an old logging skid trail. Springs, streams & other water runoff crosses the trail in several places. It is narrow with 2 to 3 man size rocks in the trail. In places there is deep mud. At one point a culvert had been washed away. Small lodge pole pines were laid across the waterway. Smaller sections were placed at 90 degrees across these to make a bridge. It is unlikely the access route will survive for any length of time without major improvements. Mr. Dick indicated the trail is covered with several feet of snow during the winter.On occasion it was necessary to use winches to gain winter access. The general elevation is 6,600 feet at the lower property boundry, and 7,500 feet at the higher end . The proporty is a long narrow parcel, going up Bear Gulch, with the unnamed creek meandering through the parcel

The property is being purchased on a contract for deed. The property consists of 60 acres and came into legal existance as a result of Mining Claim Mineral Survey No. 6536, commonly called Harlequin Placer Mining Claim . Copies of the legal instruments presented; contract for deed, no recording number, copy of warranty deed, and copy of title commitment of underlying contractor, clearly indicate the need for DNRC's legal staff review , prior of any contract commitment. Mr. Dick feels he has an unencumbered parcel with all rights. This premise is not born out by instrument review.

Mr. Dick has a wife and a baby. He is a college graduate, with a Bachelor of Arts Degree from Fresno Pacific College, Fresno, California. He earns his income by oil painting. His wife is a registered nurse. They just recently moved from Billings, Montana to the site. Mr. Dick is 30 years old. They would like to construct a 5,000 square foot home, with their own labor, from logs felled on the site, at the higher elevations of their property. Electrical power from the proposed hydroelectric system would provide for the normal house hold requirements. He would like to provide a portion of the heating from electricity, as well Mr. Dick desires a home located around the 9,000 foot level.

Electrical Load Analysis

The following is desired by Mr. Dick:

Clothes dryer	5,500 watts
Dishwasher	1,200
Small power tools	250
Freezer	440
Garbage disposal	445
Iron	1,100
Range	9,200
Refrigerator	600
Television	350
Toaster	1,100
Washingmachine	500
Water heater	5,500
Oven	8,000
Coffee maker	1,000
Lighting	1,200
	36,385 watts

Based on the desired electrical load approximately 30 kilowatts could be required at any time during the day.

With the desired electrical load, the historic average power consumed would be 40 to 60 kilowatt hours each 24 hour period.

Load summary:

30 KW Peak Power required

60KWH Average power each 24 hours

1,800 KWH each month

21,600 KWH each year

No provision is made for electrical resistance heating, for the following reasons.

1. No degree data available for the site on which to base a heat loss analysis.
2. There is no way to determine heating needs of a yet to be designed 5,000 foot house.
3. There is insufficient potential hydroelectric power available during the winter to be considered for heating.

feet down the mountain, under the State highway, and run a generator. Power thus produced would be used to heat the home in the winter,power the usual electrical load, & provide irrigation in the summer. In the proposal it was stated that DNRC's staff had measured the head & water flow. The power calculations indicated a maximum of 3 kilowatts of useable power could be generated. Due to the vagueness of site description provided by Barnard and their non-availability to assist only the section could be located, and not the exact site. It was therefore not possible to survey the site. Judgemental factors indicated that due to the very small volume of water, the 1,200 foot distance, the fact that the electrical power lines ran down the highway, very close to any point in the section, the estimated costs of $41,350 to develop the project compared to a couple hundred dollars maximum to hook up to the existing electrical power, that the project would not be feasible. The small potential of the site would not be capable of providing even a fraction of the normal electrical power requirements of a home, let alone heat it.

Due to the lack of cooperation from the grantee and the above factors, it was determined this site was not feasible. After the study was completed and submitted, I was contacted by Mr. Barnard. I was read the riot act, learned a few new verbal superfluous words , and had personal cause to suspect the motives behind the grant application. The project was not recommended for development.

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A Keuffel & Esser, K & E, surveying transit was used. The instrument was set on a rigid tripod. Each leg was secured in the soil and all clamps tightened. The plumb bob was centered over the marked and measured point where the last rule had been placed. The instrument was bubble leveled over 360 degrees. A calibrated surveying rule was used. It has an extended height of 13 feet, plus. The method used was stakes down a hill. The distance from the transit eyepiece to the point where the plumb pob was tangent to the stake was measured. The vertical distance from the stake down hill to the point of level intersection of the surveying rule, as seen through the transit telescope was recorded. The distanqe the transit eyepiece was above the stake is then subtracted from the distance measured throught the transit, for the true vertical distance between stakes. The process was repeated down the 2,850 horizontal feet covered. A calibrated steel tape was used to measure horizontal ground distance between stakes. The slope of the terrain was constant enough, to allow horizontal ground measurements. The ground measurements are close enough to be used for penstock pipe lengths. The angles, vertical distance and horizontal distance were recorded and will be retained should true horizontal distance or earth's radians ever be desired.

POWER CALCULATIONS

Basic formula to be used:

$$\text{Power, in kilowatts} = \frac{\text{Cubic ft. sec. x head in feet}}{11.8}$$

NO LOSS calculation at time of high water

$$\frac{7.96666 \text{ cfs x } 341.81 \text{ ft}}{11.8} = 230.76 \text{ KW}$$

The "no loss" power must be reduced by the following:

1. Flow at low water
2. Head loss due to penstock pipe friction
3. Turbine efficiency
4. Generator efficiency
5. Transformer losses
6. Transmission line losses

Flow at low water. Per Mr. Dick water will be one third the volume at low water. Therefore multiply flow by 0.333

Head Loss due to pipe friction. Assume PVC plastic will be used. This assumption is based on price and the smooth wall which will reduce boundary turbulence and make the flow more laminiar. Exact pipe size and composition will require a detail design and cost-effective trade-offs. For the purpose of initial baseline feasibility, assume 6 inch PVC in the region where head loss will occur. Six inch PVC has 11.787 feet of loss per 1,000 feet of pipe. Compute loss: 11.787 x 2.85(2,850 feet x 0.001) = 33.59 feet

341.81 head
-33.59 head loss
308.22 feet useable head

Turbine efficiency Only when a turbine can be designed for a fixed flow and a fixed head, can the efficiency be optimum. For a small power system, a standard turbine would be required, mainly due to the excessive cost of having a design. The most likely turbine will be a pelton wheel of some sort, again because of cost. Use 80% Turbine efficiency for initial planning purposes.

Generator efficiency. Assume 85%

Transformer losses Since transformers can be selected it is realistic to assume a maximum of 5% loss.

Transmission line losses Primary power is required. Voltage will be 2,400,7,200, or 14,400, depending on cost of wire tradeoffs with loss. Assume 5% for planning purposes.

Calculate available power as follows

$$\text{KW} = \frac{7.9666 \text{ cfs} \times 0.333(\% \text{ for low water}) \times 308.22 \text{ adj. head}}{11.8}$$

equals 69.29 KW
X 0.8 Turbine efficiency
62.4 KW
x 0.85 Generator efficiency
53 KW
X 0.95 Transformer loss @ 5%
50 KW
X 0.95 Transmission line losses
48 KW

For purposes of planning, assume 48 KW of power is available, IF Mr. Dick's estimate of low water flow is valid and if the penstock pipe is made large enough to allow unrestricted flow of water. Judgement indicates the penstock pipe costs will be such that a smaller pipe will be required. This less than ideal pipe size will further reduce the power available by one third. 48 KW x 0.666 equals 32 KW.

POWER AVAILABLE 32 Kilowatts

COST ANALYSIS

The following are required

1. A means of diversion of the water, & overflow.
2. A means to prevent trash & debries from entering the pipe.
3. A means to control the flow of water into the penstock
4. A penstock pipe from water diversion to turbine.
5. A means to control penstock to atmosphere pressure.
6. A power house.
8. A turbine
9. A generator
10. A control system
11. A primary to secondary set of transformers, 2 each.
12. A tail gate.
13. Rip-rap.
14. Direct burial primary voltage transmission lines.
15. Lightening arrestors
16. Junction box(s).

Only the significant cost items will be listed at this time.

Pipe costs at wholesale

15" SDR 30/30 gravity sewer pipe,1/8 in.wall,costs	$10.30 ft.
12" SDR-41 gravity sewer pipe, 0.305 in. wall, costs	6.00 ft.
12" PVC, 200 PSI,	18.00 ft.
10" PVC, 200 PSI,	13.00 ft.
8" PVC, 200 PSI,	8.00 ft,
6" PVC, 200 PSI,	6.00 ft.

Pipe cost, based on reducing penstock diameter & resultant power by approximately 1/3rd, plus using low pressure pipe, sewer pipe,at inlet. 13.54 inch diameter is required at the inlet during low water flow. As the pressure increases, smaller diameter pipe can be used to maintain flow.

500 feet 15" SDR 30/30 @ $10.30 ft	$5,150.00
300 feet 12" SDR-41 gravity @ $6.00 ft	1,800.00
910 feet 10" PVC, 200 PSI @ $13.00 ft	11,830.00
570 feet 8" PVC, 200 PSI @ $8.00 ft	4,560.00
570 feet 6" PVC, 200 PSI @ $5.00 ft	2,850.00
Total pipe cost	$26,190.00
2 transformers @ $500 each	1,000.00
3 lightening arrestors @ $100 each	300.00
1 Junction box	100.00
4 wire end protectors @ $100 each	400.00
4,350 feet primary wire @ $1.00 foot	4,350.00
Turbine/generator @ 30 KW capacity (estimate only)	15,000.00
Total of significant material costs:	$47,340.00

As the first cut is for purposes of determining feasibility, only the significant material costs are identified. At this point the first conclusion can be drawn. Mr. Dick will consume an equivalent of $700 worth of electricity, if it were purchased at typical public utility or cooperative rates. This figure is based on 21,600 KWH a year @ 3.24¢/KWH. The cost of significant materials only, without any labor would be $47,340. When necesary labor and required engineering assistance is added to the material cost, it would appear the cost of the project is excessive compared to the benefits obtained. One of the purposes of the grant program is to demonstrate projects to the public. Due to the location of the site, the physical access restrictions, and the climate experienced, it is extremely unlikey this site would be capable of being demonstrated to the public. To fund a system with the cabability to generate the peak power required by Mr. Dick would be tantamount to a gift of funds serving the personal needs of Mr. Dick without meeting the spirit or requirements of the program. The cost to benefit ratios, plus the lack of capability to demonstrate the project to the public, would indicate generating peak power is not feasible.

Another problem that must be solved if peak power is generated, is the question of disposing of the excess. Mr. Dick may consume 30 KW at peak loading, however, the average power consumption is approximately 2.5 KWs. The public utility power is 7,535 feet away from the potential generating site, and would cost approximately $25,270 to bring in a transmission line to accept the surplus, plus an additional $10,000. to $15,000. worth of connecting equipment. It does not seem prudent to bring in utility power to accept the excess. The other means available are either control or dissapation. Both are technically feasible, but require additional and significant expense.

Summary of the concept: "Generating Peak Power Constantly"

Generating peak power constantly is not feasible because of excessive costs for a small return, not in keeping with the Renewable Energy Bureau's Program 's goals & requirements, and the inability to demonstrate the project to the public.

STORING ELECTRICITY

In-as-much as generating peak power is not feasible, a second feasibility study to determine the feasibility of generating average power, storing the energy until needed, and then developing a peak generating system , was conducted.

The basic concept is to generate electrical power at the "essential net average", 24 hours each day. The energy is stored in deep-cycle batterys. When peak power is required it is generated from storage. The lead-acid battery is the only reasonable cost means of storage for a remote site.

The system was derived and designed as follows.

60 KWhours consumed each 24 hours = 2.5 KWH average each hour.

If 2.5 KWH are actually consumed, good engineering judgement of the losses in a battery system require a system capable of generating twice this amount of power, or a 5 KW system.

The first step is to determine the head requirement for a 5 KW system.

$$\frac{7.9666 \text{ CFS} \times 0.3333 \text{ (low water)} \times \text{unknown head}}{11.8} = 5 \text{ KW}$$

Head, with no loss, is then 22.24 ft.

To account for an increase in friction through the pipe in time, and the slow deteriation of the capability of the battery to store for prolonged periods of time the head should be increased approximately 30%. A head of 31.375 ft. will be used for design purposes.

Calculations continue:

$$\frac{7.9666 \text{ CFS} \times 0.3333 \times 31.375 \text{ ft}}{11.8} = 7 \text{ KW (no loss)}$$

Referring to the elevation survey 300 feet of penstock will produce 31.375 foot head. The pipe loss is negligible at 300 feet and will be neglected for the purpose of initial feasibility calculations. The system will be sized for 300 ft of pipe, 31.375 foot head, producing a no loss 7 kws. This will support a net 2.5 KW actual consumed average power system.

Battery design: Battery storage is difficult to predict under ideal conditions. Less than ideal conditions will be experienced at this site. The number of batterys required, plus compliance with the National Electrical Code, dictate a special facility be constructed to house the banks of batterys. The structure must have positive venting. This means a winter operating environment where the battery is cold. If the battery is kept at full charge, the lifetime should be or better stated, could be 10 years. The chemical change, commonly called sulfating, takes place as a function of level of charge maintained. The trade-off is between the number of initial batterys and the life time, measured in cost.

There are two battery systems possible. The first is to wire all high power, non-frequency dependent, elements in the house to battery power. A bank of 18 12 volt batteries connected in series would produce 216 volts D.C., adequate for conventional elements requiring 220 volts A.C.. For example, the heating elements in an electric dryer could be connected to a 216 volt D.C. source and function normally, if the battery bank had sufficient capacity. The generator would be connected to the normal convenience A.C. receptacles for low power 60 cycle use. The battery bank would be center taped to provide 108 volts D.C. for the equivalent of 110 volts A.C.. The second approach is to wire the house in a conventional manner, and connect an inverter to the battery bank to provide the amount of A.C. power on demand.

The first step is to size the capacity of the battery bank. This is computed as follows on the basis of a bank of 18 12 volt batterys in series.

30 KW, 30,000 watts, is the peak power required for the Dick home. 18 batterys in series produce 216 volts.

30,000 (watts) ÷ 216 (volts) = 138 (amps) ohm's law

To produce 30 KWs of power, a bank of 18 batterys in series would have to provide 138 amps current flow. Since the batterys are in series, 138 amps would be flowing through each. Each battery is 12 volts. The power per batteryis computed as follows:

138 (amps) x 12)volts) = 1,656 watts

Each 12 volt battery must deliver 1,656 watts to provide the 30 KWs required at peak power. Sears type 48 battery specifications indicate it will supply 262 watts for 205 minutes. It will supply 6,720 watts for 30 seconds as well. Assume the battery will be allowed to discharge 25% of its capacity. (This is an iteriative analyses to optimize initial cost of a battery bank with life cycle time, & measured in discharge%). Further assume the peak power will be required for one hour. The requirement per 12 volt battery bank then becomes to supply 1,656 watts for 60 minutes and discharge only 25% of capacity. 3.316 hours (205 minutes divided by 60 minutes) at the rate of 262 wwatts is the Sears type 48 battery capacity. 3.316 (hr) x 25% (desired discharge) = 0.854 hours. The single battery could produce 262 watts for 0.854 hours and consume 25% of its capacity. 1,656 watts required divided by 262 watts provided per battery equals 6.32 batterys connected in parallel. 6.32 batterys, in parallel, would produce 12 volts at 1,656 ~~watts,~~ for 0.854 hours and consume 25 % of their capacity. 1.0 (desired hour of power production) divided by 0.854 (hours of capable production of 6.32 batterys) equals 1.171 times 6.32 batterys equals 7.4 . 7. 4 Sears type 48 batterys, connected in parallel will then produce 12 volts at 1,656 watts for one hour and consume 25% of their capacity. Rounding of the 7.4 to 8, the design becomes 8 batterys connected in parallel, with 18 of these banks connected in series, for a total of 144 Sears type 48 batterys. The system of batterys will produce 30 KWs for one hour and consume 25% of the battery capacity. This completes the battery analysis.

In the case of Mr. Dick, should a battery storage system be deemed feasible, an inverter would probably be required. An engineer would have to design the entire house wiring and the reqiring of all appliances to work on a D.C. system,with normal A.C. outlets. It is unlikly an engineer would be available for the project. The system is then costed as follows.

150 feet of SDR 30/30 gravity sewer pipe @ $10.30 ft.	$1,545.00
150 feet of SDR-41 gravity sewer pipe @ $6.00 ft	900.00
2 each transformers @ $500 ea	1,000.00
2 each lightning protectors @ $100 ea	200.00
2 each wire end protectors @ $100 ea	200.00
1,800 feet primary wire @ $1.00 ft	1,800.00
144 batterys @ $50 each	7,200.00
Controller	1,800.00
Turbine/generator	7,000.00
Inverter @ 30 KW 110/220 VAC	12,000.00
Total of significant material costs	$33,645.00

Summary of the concept:" STORING ELECTRICITY"

The only difference between storing electricity and generating peak power, as far as Mr. Dick would be concerned, is the cost. When the battery facility and the additional engineering costs are added to the storage method, there will be little difference in costs. For the identical reasons stated in the summary on generating peak power, storing electricity is not feasible either.

BRINGING IN PUBLIC POWER

For purposes of comparsion and puting the prices into the correct perspective, the cost of bringing in electricity was examined. Mr. Dick states electricity is available from a public utility 7,485 feet from his property line. From the power line to the site of Mr. Dick's proposed home, is 11,885 feet. The typical cost of bringing in power is $2.00 per foot, plus mileage for the crew.

Cost to bring in power is therefore estimated:

11,885 feet x $2.00 per foot =	$23,770.00
Mileage estimate	1,500.00
Total cost	$25,270.00

General comments on the project

Mr. Dick desires to place his home approximately 1,500 feet above the potential dam site, in the 8-9,000 foot elevation area of Bear Gulch.A minimum of 4,350 feet of high voltage transmission line would be required, for a system producing peak power, and 1,800 feet for an average power system. These systems are dangerous. Mr. Dick does not have the knowledge, training, or experience to service such a system. Due to the remoteness, lack of access and the weather, any malfunction would not be taken care of until summer. Malfunctions could occur that would destroy the system, cause personal harm, and start a forest fire. Mr. Dick indicated he would like to construct an earth dam to impound 20 feet of water, making a lake for fishing. Mr. Dick does not posess the knowledge to construct such a dam. The soil overburden, permeability of the subsurface structure and lack of suitable foundation all preclude and water depth over that requsite for a small water diversion site. The site is in a gulch/canyon area. Any sudden runoff would breach the dam. Dear, elk & bear frequent the area, as well as burrowing rodents. All would undermine a dam. A large dam of any design is not feasible. Under no circumstances should a dam be constructed that would impound significant quanities or depths of water. Dam failure would endanger life and property at lower elevations. Mr. Dick was not aware of a concerne.. There is insufficient materials available locally to construct a dam foundation, seal, and preclude seepage. Without these any dam would fail in time.

LEGAL CONSIDERATIONS

Attached to this engineering report are copies of:

1. Contract for deed
2. Warranty deed
3. Schedule B, Title Co. commitment showing title vested in the name of Wayne E. Stephens with the proposed insured being Kenneth V. Ward.

If DNRC considers funding this proposal, a carefull legal review of these documents is urged.

Mr. Dick is purchasing this property on a contract for deed. The land is subject to several underlying instruments.

SUMMARY & RECOMMENDATIONS

Cost summary:

Opt A	Cost to generate peak power, materials only	$47,340.00
Opt B	Cost to generate average power & store, materials only, & no required engineering effort	$33,645.00
Opt C	Cost to bring in public utility	$25,270.00

The project can not be demonstrated to the public as the site is remote, literally inaccessible due to weather and access route. Any expenditure of funds would amount to an outright grant to Mr. Dick without public benefit. Mr. Dick does not posess the skills, knowledge or experience necessary to perform the tasks required of such a project. An equivalent of $700 worth of electricity would be consumed each year. The above costs to this benefit is a very poor return on the dollar. The project is physically unsafe to Mr. Dick, the area of water diversion, the pipe line, & the life & property of those downstream in the event of a failure. A primary power transmission line, with a high voltage between 2,400 to 14,400 volts would be on site. This is extremely dangereous in the proposed environment. The project is determined to be not feasible & should not be considered for funding.

ENGINEERING REPORT

To

Renewable Energy Bureau
Energy Division
Department of Natutal Resources
and Conservation
32 South Ewing
Helena, Montana 59620

Prepared by:

Richard G. Wrench
295 Highland Drive
Kalispell, Montana 59901
Phone: 257-8575

Contract No. 650-810
Effective Date: 5/6/81
Contract Amount: $8,500.00

Nature of Contract

Performance of feasibility studies and system design analysis at four potential microhydro sites

Report on:

Mr. James W. Murnion
Box 55
Shawmut, Montana 59087
Phone: 575-4435

"Overshot water power project
Electric Power for mining & milling
hard rock."

Submitted

Richard G. Wrench

Recommendation: The use of the proposed water wheel is not feasible. The project is recommended for funding at an anticipated cost of $23,525.00, for implementation of a turbine/generator system. This approach is feasible.

GENERAL COMMENTS

The site investigated is located in the Castle Mountain mining area. The site is on a potential mill site, located on Boulder Creek, 1-2 miles west of what once was Castle Town, an old mining settlement, located in Meagher County, in Section 13, Range 8 North, Township 8 East. This area is approximately 65 miles east of Helena. Before the turn of the century, the entire area was the scene of extensive gold and other hard rock mining activity. Legal use of the land, which is under control of U.S. Bureau of Land Management, is dictated by the Federal Mining Act. Mr. Murnion has properly staked a claim to 40 acres, marked the 4 corners as prescribed by law, and is working the claim. Deed to the land is provided after 6 years. Mr. Murnion intends to mine gold bearing ore by drilling into vertical seams of the vein, blasting the stratum into smaller rocks, and then hauling the rocks to a ball mill. The rocks will be pulverized by the ball mill. The resultant powder will be processed to extract the gold. Mr. Murnion desires to construct an overshot water wheel on Boulder creek to drive an electrical generator to produce the power required to operate the mining equipment. The mine would employ 2 to 3 individuals. Without electrical power, the mining operation would be performed by hand power, seriously hampering productivity. Access to the site would require the improvement of a trail. This does not appear to pose any legal or practical problem. Mr. Murnion is a man who has the capability to make things happen. He is a rancher, living 13 miles NE of Shawmut, Montana. He owns the necessary heavy equipment for road construction and mining operation. There is no question, but he has the capability, judgement, and experience to successfully undertake his mining and electrical generating project. He has extensive experience in comparable construction in northern Alaska and the Artic. Mr. Murnion has planned and is implementing his project on a logical, step by step basis. He is being guided by a Mr. Leon Furguson, an engineer with a background designing aircraft electrical systems. Public access to the demonstration project would be limited to summer, as the area is subject to winter snow pack. This project should be ongoing for many years, if not indefinitely.

ELECTRICAL LOAD ANALYSIS

Mr. Murnion desires to operate the following:

Ball mill @ 10 H.P.	7.455	KW
Air Compressor @ 10 H.P.	7.455	KW
Lighting	0.3	KW
Refrigerator	0.5	KW
Deep freeze	0.4	KW
Small heater	1.2	KW
Misc.	1.0	KW
Total	18.31	KW

SPECIFIC DATA GATHERED

Flow measurements

Width of the waterway: 13 feet-6 inches

Depth measurements: (all figures are in inches)

7,8,10,5,12,10,8,14,18,10,8,6,4
Average depth was 9.23 inches, 0.7692 ft.

Water velocity:

Float distance measured was 40 feet
Float time, in seconds, for each time a float was measured
6,6,5½,4½,5,5,4½,5½,5½,5 Average 5.25 seconds

Method used

Depth measurements were taken at equal divisions across the point where the width was measured. The width was measured by a steel tape. A distance of 40 feet was measured on the stream bank. A line was marked perpendicular to the flow, at each end of the 40 feet distance. A wooden float, with 2/3rds of its height submerged was placed up stream. Time was started when it passed the first line and stoped when it passed the second. Any float that swirled was discarded.

Flow calculation

The following formula was used to calculate flow.
The width of the stream, in feet, times the depth, in feet, times the distance the float travels in one minute, times the constant, 0.8, equals the cubic feet per minute flow.

Width of stream: 13.5 feet
Depth of stream: 0.7692 feet
Average flow time: 5.25 seconds
Flow distance: 40 feet

Calculate CFM as follows

13.5 x 0.7692 x 0.8 x (60 ÷ 5.25 x 40) = CFM

CFM = 3,797 ÷ 60 = 63.28 CFS Flow 6/15/81

Mr. Murnion stated that during the period of time he intended to use the site, the flow would be reduced by 10% of that measured.

63.28 CFS x 0.9 = 56.95

Therefore, per Mr. Murnion, the design flow for use: 56.95 CFS

ELEVATION MEASUREMENTS

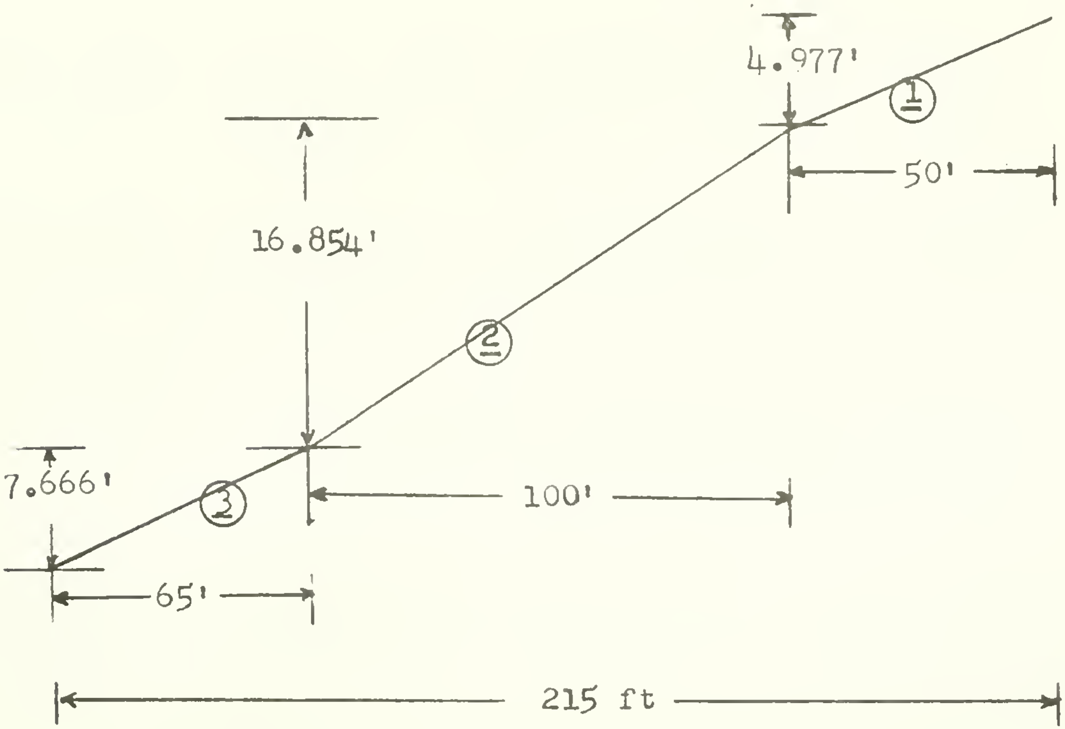
A potential site for water diversion was selected. The point was in the area where Mr. Murnion wishes to build his ball **mill** and a cabin. The site was adequate to divert sufficient water without disrupting the normal stream flow. The point of diversion appears quite ideal. Elevation measurements were taken for the first 50 foot horizontal distance, the next 100 feet, and finally the last 65 feet.

Horz. Distance	Head/meas. dist.	Head	Penstock
First 50 feet	4.997 foot head	4.997 ft	@ 50 ft
Second 100 feet	16.854 foot head	21.851 ft	@ 150 ft
Third 65 feet	7.666 foot head	29.517 ft	@ 215 ft

A total of 215 horizontal feet was measured. The reason for the incremental measurement was the abrupt change in the creek slope. The first 50 feet was a uniform grade, the next 100 feet was also uniform grade, but steeper, the last 65 feet was uniform and different. The elevation was broken into three sections to define specific grade and to cover the region of potential generator location.

Uniform grade as follows: vertical drop/horizontal dist.

①	First 50 foot horizontal distance	0.09994 ft/ft
②	Second 100 foot horizontal distance	0.16854 ft/ft
③	Third 65 foot horixontal distance	0.11793 ft/ft



Method of elevation measurements

A Keuffel & Esser, K & E, surveying transit was used. The instrument was set on a rigid tripod. Each leg was secured in the soil and all clamps tightened. The plumb bob was centered over the point where the last rule had been placed. The instrument was leveled, over 360 degrees, by bubble adjustment. A calibrated surveying rule was used. It extends to over 13 feet. The method used was stakes down the hill. Looking through the transit telescope the distance was measured on the rule and recorded. From this measurement, the distance from the centerline of the transit eyepiece to the prior stake, located under the transit, by the pumb bob, is subtracted. The resultant measurement is the true vertical elevation between the two points of measurement. The horizontal distance was measured by a steel tape.

POWER CALCULATIONS

The basic formula to be used is:

$$\text{Power in kilowatts} = \frac{\text{Cubic feet per second x head in feet}}{11.8}$$

Four cases will be considered:

Flow: 56.95 CFS
Case A: first 50 ft. head is 4.997 ft
Case B: second 100 ft. head is 16.854 ft
Case C. first 150 ft. head is 21.851 ft
Case D. First 215 ft. head is 29.517 ft

Case A $\frac{56.95 \times 4.997}{11.8} =$ 24.12 KW no loss power first 50 ft

Case B $\frac{56.95 \times 16.854}{11.8} =$ 81.34 KW no loss power 2nd 100 ft

Case C $\frac{56.95 \times 21.851}{11.8} =$ 105.46 KW no loss power 1st 150 ft

Case D $\frac{56.95 \times 29.517}{11.8} =$ 142.45 KW no loss power 1st 215 ft

The above "no loss" power must be reduced by the following:

1. Flow at low water, if any.
2. Head loss due to pipe friction.
3. Turbine or water wheel efficiency.
4. Generator efficiency.

There are two options to be considered for this site:

Option A is a turbine generator.

Option B is a waterwheel generator.

Turbine generator

Electrical load 18.31 KW divided by 0.8 for turbine efficiency equals 22.8875 KW, divided by 0.85 for generator efficiency equals 26.92 KW. A system should be designed with a no loss of 27 KW to use a turbine/generator combination. The pipe loss can be ignored at this short distance and large pipe diameter.

The design would be computed as follows:

$$\frac{56.95 \text{ x Head}}{11.8} = 27 \text{ KW}$$

$$\frac{27 \text{ x } 11.8}{56.95} = \text{Head} \qquad \text{Head} = 5.594381 \text{ ft.}$$

Drop first 50 ft: 4.977 ft

Slope next 100 ft is 0.16854 ft for each horizontal foot of pipe

$$\begin{array}{ll} 5.594 & \text{Required head} \\ \underline{-4.977} & \text{Head from first 50 ft.} \\ 0.617 & \text{ft required from 2nd 100 ft} \end{array}$$

divided by 0.16854 = 3.66 ft.

Penstock pipe requires 53.66 horizontal feet, with a head of 5.6 feet, capable of carrying 56.95 cubic feet a second.

Pipe diameter computed as follows:

Stream width: 13.5 ft

Stream depth: $\underline{0.7692 \text{ ft}}$

10.38 square feet required for penstock pipe

Area of a circle = Pie R^2

10.38 sq.ft = 3.14159 R^2

$$R^2 = \frac{10.38}{3.14159}$$

R^2 = 3.304

R = 1.8177 ft x 2 = 3.635 ft diameter x 12 = 43.62 inch

43.62 inch pipe is required for the penstock; use 48 inch.

The head of 5.6 feet, with a liminar flow will produce approximately 13 PSI, so high pressure pipe is not a requirement.

The turbine/generator system can now be priced.

55 feet of 48 inch spiral galvanized pipe @ $25 ft		$1,375.00
Turbine/generator,20 KW capacity (estimate only)		15,000.00
Controller		3,000.00
Valves		150.00
Concrete & misc.		500.00
Electrical		500.00
Material cost	Total	$20,525.00

It is assumed Mr. Murnion will provide his own labor. A yet to be determined amount of onsite engineering will be required. It is estimated that 2-$3,000 will be needed

Engineering salaries $3,000.00

Total estimated cost $23,525.00

Waterwheel/generator

Mr. Murnion has a water wheel in his posession that he wishes to use. There is no way to examine a water wheel and specify how much power it will produce. The wheel must be physically installed and the shaft brake horse power measured. At this point the horse power can be translated into electrical power with reasonable assurance. Mr. Murnion desires to control the electrical power output by means of a yet to be designed water flow regulator. What ever power being produced will be consumed by the two main loads, a 7.455 KW ball mill and a 7.455 KW air compressor. Each piece of equipment consumes 40% of the design load. Assume that one piece of equipment is operating. The overshot water wheel has been provided with sufficient water falling over the buckets to stabilize at the load generating requirements. Now assume another piece of equipment is thrown on the line, increasing the load by an additional 40 %. The controller instructs the flow regulator to increase the flow. The weight of the wheel, empty, is estimated to be 2,500 pounds. The physics of mass inertia dictate an indeterminate amount of time will be required before a steady state at a higher power level can be obtained. This power level will have two essential parameters. The first will be time, The second will be shaft RPM.

Consider the effect of time. A 10 horse power motor, in this application, is a high touque starting design. The starting voltage, and phasing is critical. At the time of initial load the generator will be unable to supply the voltage within the operating limits of the motor. The current is dissapated as heat and not work. The result is a burned out motor and a probable fire in the unit that is trying to get up to speed with the starting winding. In the unit that is already on its run winding, its operating limits will be exceeded, and it will cycle between run & start windings until it too converts current flow from work into heat. The result is two burned out motors and two probable fires.

Consider the effect of RPM. Power in a water wheel, is controlled by the amount of water provided to the wheel. Increase the volume and the speed of the wheel increases. If the wheel must increase its power by 40%, neglecting losses for the moment, its speed will vary dramatically. As the water wheel turns relatively slow, compared to the RPM of a generator, any minor change in the wheel RPM will translate to a major change in the RPM of the generator. For a water wheel to function satisfactorily, it must be in a steady state constantly. A flow regulator is usefull only to make minor adjustments to shaft brake horse power within small RPM limits. To incorporate an already built overshot water wheel, it would have to be installed. The wheel should be operating with full water force. The RPM should then be monitored as a function of varying brake loading and shaft horse power. The effect of the flow regulator should then be measured. Curves, showing RPM as a function of brake horse power and time to make the transition between the curve, as a contineous monatonic function, are required to design the generator and the gear ratio between the water wheel shaft and the generator. At this point, a design load could be determined.

In defense of historic water wheel electrical power applications, the designs have been empirical, cut and try. The power factors of the electrical motors were traditionally around 0.5, half heat and half work. During initial design many burned out until the right combination of load and RPM was found. All recorded successful applications are of the steady state.

In an endeavor to analyze Mr. Murnions water wheel for application its physical parameters were recorded and translated into the best engineering approximations.

The bucket dimensions are: 11" x 26" outside, 18 " deep, 7 " x 26 " inside.

The volume of a bucket is then 4,212 cubic inches or 2.4375 cubic feet. At 62.38 pounds of water/cu. ft, a full bucket would contain 152.05 pounds of water. This equates to 18.166 gallons of water.

Refer to the engineering sketch. The top bucket, # 1, will be assumed full, and contain 152.05 pounds of water. It has a lever arm of 0.625 feet. This means that 152.05 pounds of force are exerted on a lever arm of 0.625 feet. Using the laws of physics this is easily translated into horse power. The difficulity in this approach is how to estimate friction losses, which are completely unknow. Also unknow is the effect of the force of the water coming from the pipe. It could have an appreciable effect if the force of the water hitting the bucket were to add work. The maximum pressure will be less than 15 PSI, so it is doubtfull that any force, other than the water weight can be considered. At best, any force could offset frictional losses.

Based on the measured geometric parameters of the water wheel Murnion owns, the foot pounds will be estimated. The calculations are based on the assumption that bucket number one will be full in the position shown, and that bucket number 10 will be empty in the position shown. The force center line of the water in the first 9 buckets is determined. It is assumed all weight is exerted at this point. The lever arm to the center line of the axle is then calculated. The foot pounds of force of each bucket is then calculated. Finally, the total foot pounds theoretically possible is determined.

The calculations are summarized as follows.

Bucket Number	Water Weight	Lever Arm	Foot Pounds
1.	152.05 lbs	0.625 ft	95.03
2.	135.14	1.4	189.196
3.	118.24	2.05	242.92
4.	101.35	2.6	263.51
5.	84.463	3.15	266.058
6.	67.57	3.5	236.495
7.	50.68	3.4	172.312
8.	33.788	3.25	109.811
9.	16.892	2.9	48.986
		Total foot pounds	1,624.318

The power of a force is the rate of its doing work. The force has been approximated. The rate can only be measured. One horse power equals 550 ft-lb per sec equals 0.7457 kilowatt. The work performed by the water wheel must, by definition, be the force applied, less the force to overcome friction, or air, or any other resistance. The limits are the potential energy of the 56.95 CFS of water at a head of approximately 30 feet, the indeterminable kinetic energy of 56.95 CFS of water at approximately 13 PSI, if it is capable of imparting angular velocity to the wheel, the rate of bucket fill and empty, friction, air resistance and unknown resistance.

These unknown parameters can only be approximated, not determined. The approach will then be to determine the speed, RPM, that the wheel must turn inorder to produce the required power, and then test the forces involved to see it is possible and reasonable. This is determined as follows.

Assume the same conditions as the turbine/generator case.

No loss design starting load is therefore 27 KW.

27 (KW) divided by 0.7457 (ft-lb/sec) = 36.20759

36.20759 times 550 (ft-lb/sec.) = 19,914.174 ft-lb/sec req.

19,914.174 (ft-lb/s req.) ÷ 1,624.318 (ft-lb weight) = 12.26

19,914.174 foot pounds of force are required each second. When the water wheel is in a steady state it produces 1,624.318 foot pounds of force. Force times rate equals work, therefore: The water wheel must turn 12.26 times each second to produce the work required. Multiply times 60 and the water wheel must turn at 735.6 RPM.An engineering opinion, which would require testing to validate, is that the effect of journal friction, air resistance, and the ratio of wheel mass to force, would preclude this velocity. In any event the requirement for this specific wheel is to rotate at 735.6 RPM to produce the required load.

Next, let us examine the factors that control RPM.

Available water: 30 buckets are estimated around the wheel perimeter(Note: the exact number is unimportant. What is important is the water volume, which will be a constant). Each bucket holds 2.4375 cubic feet. If the wheel is to rotate at the required 12.26 times a second, 30 (buckets) times 12.26 (revolutions required each second) requires 376.8 buckets must be filled each second. The water flow available is 56.95 cubic feet each second. Divide 56.95 cubic feet of available water each second by the bucket capacity of 2.4375 and only 23.364 buckets can be filled each second. If 376.8 are required and only 23.364 can be filled, then 23.364 divided by 367.8 equals 0.635,or 6.35% of the power required is available to be converted into work.As the basic limitation is the lack of available water, there is no point in trying to quantify journal friction, air resistance & mass to force ratio at a required operating RPM.

The probable power available is then calculated by multiplying the design 27 KW times the effect of water volume limits. 27 x 0.0636 = 1.7145 KW at no loss. When losses are applied the useable electrical power becomes 1.46 KW.The weight of the water contributing work at any one time is 760.173 pounds. The weight of the wheel is estimated at 2,500 pounds. The ratio of work force to mass is 0.304 to 1, a very unfavorable ratio.

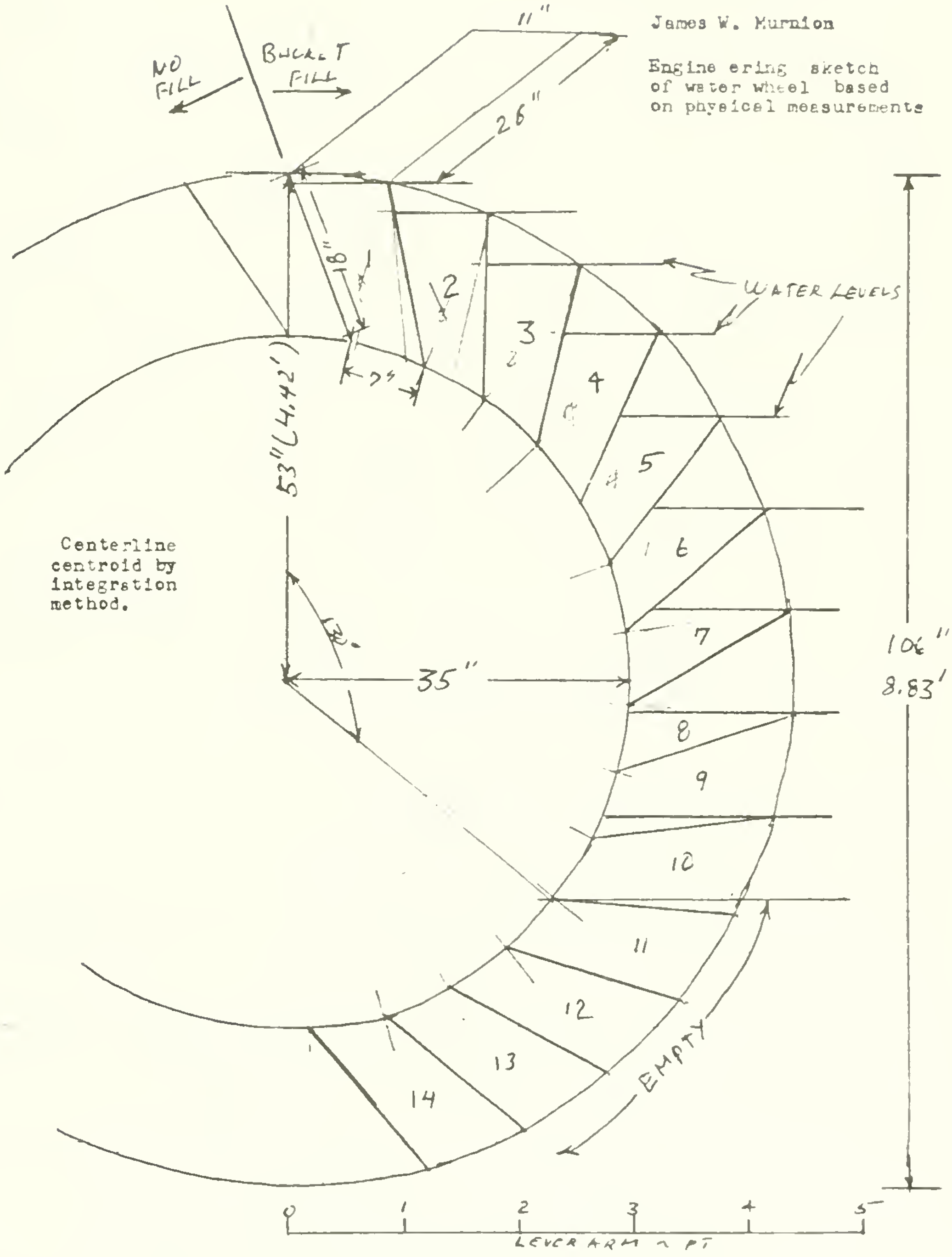
WATER WHEEL SUMMARY

A water wheel must run at a steady state, constant speed and load to be effective. An analsis of the power this wheel is cabable of producing with the available water, indicates 1.46 KWs of power will be the maximum. The load required is 18.31 KW. In his proposal and subsequent discussions, Mr. Murnion assumed initial power calculation based on an 8 foot head, and some kenitic work being generated by the water in motion into angular velocity of torque. While this is the traditional method used to determine power from a turbine, it does not apply to an overshot watter wheel. Force, translated into work over time is determined by potential energy, by virtue of the water wheel configuration. The buckets are "filled" with water. It is the weight of the water that provides the force that turns the water wheel. Newton's second law of motion is inviolate, and must be applied as the criteria of force in determining the power from a water wheel. "Change of the motion of a body is proportional to the force and to the time during which the force acts, and in the same direction as the force." The force is the weight of the water.

Mr. Murnion states his power requirements can be adjusted to what the wheel will turn out. If the wheel will "turn out" only 1.46 KWs and a single ball mill requires 7.455 KWs, the water wheel does not have the capability to supply the most fundamental need of the project. It is therefore not feasible. This will be very sad news for Mr. Murnion, as he has an understandably strong feeling about using his water wheel. He said this wheel ran a saw mill & it took a 225 H.P. deisel engine to do the same job.. He feels this wheel will run a 50 Kw generator. I only wish the numbers could have verified his faith.

SUMMARY & RECOMMENDATIONS

The water wheel is not capable of producing the 18.31 KWs of power required. It will produce 1.46 KWs, and is therefore not feasible for the project. The project is very feasible if a turbine/generator approach is taken. The estimated cost is $23,525.00. The public will be able to view the site for demonstration purposes during the summer. There is no ecological reason not to recommend the project. The project will create employment for 2 to 3 people for an indefinite time. If the budget is within limits, the project is therefore recommended for a turbine/generator combination.



James W. Murnion

Engineering sketch of water wheel based on physical measurements

Centerline centroid by integration method.

ENGINEERING REPORT

To

Renewable Energy Bureau
Energy Division
Department of Natural Resources
and Conservation
32 South Ewing
Helena, Montana 59620

Prepared by:

Richard G. Wrench
295 Highland Drive
Kalispell, Montana 59901
Phone: 257-8575

Contract No. 650-810
Effective Date: 5/6/81
Contract Amount: $8,500.00

Nature of Contract

Performance of feasibility studies
and system design analysis at four
potential microhydro sites

Report on:

Merle B. Jore
Route # 2, Box 58A
Ronan, Montana 59864
Work phone: 675-2610
Home phone: 644-2542

"Feasibility Grant Request for a
Hydroelectric System for Home Use.
Excess, if any, to be Fed Back to
Power Grid."

Submitted
Richard G. Wrench

Recommendation: This site is feasible for development. It is in excess of 200 KWs, larger than the scope of microhydro power demonstration. The site should be developed with private funds for profit.

GENERAL COMMENTS

The site investigated is located approximately 8 miles southeast of Ronan, Montana, on the western slope of the Mission Range Mountains. The site is located within the Flathead Indian Reservation, and is orgionally a homestead. Access to the property is by gravel road. The road is adequate except for winter snow, when the public would be denied practical access for purposes of viewing the site. Mr. Jore has owned and lived on the property for 20 years. There is primary power to the site. The power serves the Jore's home, continueing past the home to a smallerbuilding used as a "warming hut" for Mr. Jore's ski run. Initially, Mr. Jore requested a feasibility study to determine the potential capability of the site. He owns a large dozer and is posessed with the skills and judgement for its use. He is a man of much experience and should be capable of implementing much of the design, should the site be developed. He would like to consider using the electrical power generated to heat a portion of his 1,500 square foot home, provide his domestic electrical needs, and sell the excess to the utility company.

Electrical load analysis

Domestic needs	30	KW peak
	40	KWH each 24 hours
	1,200	KWH each month
	14,400	KWH each year
Heating *	20	KW peak
	120	KWH each 24 hours in January
	3,600	KWH January heating
	21,557	KWH Annual heating requirement

* Heating is an engineering estimate based on Mr. Jore's 1,500 square foot home, $3\frac{1}{2}$ inch wall, & $6\frac{1}{2}$ inch ceiling insulation.

Load summary:

30	KW peak power required without elect. heat
50	KW peak power required with elect. heat.
1,200	KWH required each month without heat
14,400	KWH required each year without heat
35,957	KWH required each year with heat
4,800	KWH required January with heat.
4,246	KWH required February with heat
3,763	KWH required March with heat
2,894	KWH required April with heat
2,299	KWH required May with heat
1,782	KWH required June with heat
1,377	KWH required July with heat
1,472	KWH required August with heat
2,095	KWH required September with heat
2,903	KWH required October with heat
3,798	KWH required November with heat
4,520	KWH required December with heat

Specific data gathered

Two waterways were measured. One was a stream. The other was a spring.

STREAM MEASUREMENTS

Case A

Width: 8 ft-11 in

Depth measurements (all in inches)
6,13½,11½,10,12,14 3/4,18 3/4,14,15,15,14,15,11,11,11,11
Average depth was 12.71875 inches, 1.05989 ft
Float distance measured was 27 feet
Float time for each time a float was measured
3,3,3¼,3¼,3,3,3,3¼,3,3¼,3 Average 3.09099 seconds

Case B

Width: 8 ft-11 in

Depth measurements (all in inches)
7,10,11,19,15,16,15,11,16,15½,15½,15½,15½,12½,12½
Average depth was 13.8 inches, 1.15 feet
Float distance measured was 27 feet
Float time for each time a float was measured
3,3,3¼,3¼,3,3,3,3¼,3,3¼,3 Average 3.09099 seconds

Case C

Width: 8 ft-11 in

Depth measurements (all in inches)
7,8½,10,14,15,16,16½,16½,16,14½
Average depth was 13.4 inches, 1.1166666 feet
Float distance measured was 27 feet
Float time for each time a float was measured
3,3,3¼,3¼,3,3,3,3¼,3,3¼,3 Average 3.09099 seconds

Method used

Depth measurements were taken at equal divisions across the point where the width was measured. The width was measured by a steel tape. A distance of 27 feet was measured on the stream bank. A line was marked perpendicular to the flow, at each end of the 27 foot distance. A wooden float, with 2/3rds of its height submerged was placed up stream. Time was started when it pasted the first line and stoped when it passed the second. Any float that swirled was discarded.

The following formula was used to calculate flow. The width of the stream, in feet, times the depth of the stream, in feet, times the distance the float travels in one minute, times the constant 0.8, equals cubic feet per minute of flow.

Width of stream: 8.91666 feet
Flow distance: 27 feet
Average flow time: 3.09099 seconds
Average stream depth: 1.108854 feet

Calculate CFM as follows

8.91666 x 1.108854 x 0.8 x (60 ÷ 3.09099 x 27) = CFM

CFM = 4,145.6877 ÷60 = 69.094795 CFS Flow 6/18/81

This flow was recorded June 18, 1981. There is no recorded flow data on which to base low water. Mr Jore indicated the flow would be reduced by half during low water.

Reducing the above flow per Jore, 34.547393 CFS @ low water

SPRING MEASUREMENTS

Case A

Width: 4 ft-0 in

Depth measurements (all in inches)
1 3/4,2,2½,3¼,4¼,4½,5 3/4,6½,5,6½,6½,6,5,5,4,3,2,1
Average depth was 4.115 inches, 0.3429166 ft
Float distance measured was 16 feet
Float time for each time a float was measured
5,7,5,5,5,5,5 Average 5.2857 seconds

Case B

Width: 4 ft-0 in

Depth measurements (all in inches)
4,4,5,4½,4,4,4,3 3/4,4,4
Average depth was 4.125 inches, 0.34375 feet
Float distance measured was 16 feet
5,7,5,5,5,5,5 Average 5.2857 seconds

Method used

Same as stream above.

Using the same formula as the stream above,; the flow is calculated as follows.

Width of the spring: 4.0 feet
Depth of the spring: 0.34333 feet
Average flow time: 5.2857 seconds
Flow distance: 16 feet

Calculate CFM as follows

$$4.0 \times 0.34333 \times 0.8 \times (60 \div 5.2857 \times 16) = \text{CFM}$$

$$\text{CFM} = 199.54 \qquad \div 60 = \underline{3.32567 \text{ CFS Flow } 6/18/81}$$

Mr Jore states the spring flow is constant year around

ELEVATION MEASUREMENTS

A potential site for water diversion was selected. Precise elevation and distance measurements were taken from the point of diversion to a point where a powerhouse would be feasible. The powerhouse was selected far enough away from the lower property line to allow room to rip-rap the area below and still remain on Mr. Jore's property. The head of the stream measured 418.149 feet. This is from the water level at point of diversion to an approximate level of turbine inlet. The head of the spring measured 402.465 feet, with same qualifications as stream. The penstock distance for the stream is approximately 2,400 feet. A detailed engineering trade-off is required to to establish the potential tie-in point of the spring water pipe to that of the stream water pipe, should they be connected into a single penstock. The length of the penstock for a separate spring system would be approximately 1800 to 2,000 feet.

Method of elevation measurements

A Keuffel & Esser, K & E, surveying transit was used. The instrument was set on a rigid tripod. Each leg was secured in the soil and all clamps tightened. The plumb bob was centered over the point where the last rule had been placed. The instrument was leveled, over 360 degrees, by bubble adjustment. A calibrated surveying rule was used. It extends to over 13 feet. The method used was stakes down the hill. The distance measured on the rule was recorded. From this measurement, the distance from the centerline of the transit eyepiece to stake under it, was subtracted, to determine true vertical distance. A steel, 100 foot tape, was used to measure the distance between stakes. A total of 3,693 feet were surveyed. Both the stream and the spring were surveyed.

POWER CALCULATIONS

Basic formula to be used:

$$\text{Power in kilowatts} = \frac{\text{Cubic ft. per sec. x head in feet}}{11.8}$$

STREAM CALCULATIONS

NO LOSS calculations at time of measurement

$$\frac{69.095 \times 418.149}{11.8} = 2{,}448.5 \text{ KW no loss high water}$$

Reducing flow by 50% per Mr. Jore: 1,224.25 KW no loss, low flow

SPRING CALCULATIONS

NO LOSS CALCULATIONS at time of measurement

$$\frac{3.32567 \times 402.465}{11.8} = 113.4 \text{ KW no loss constantly}$$

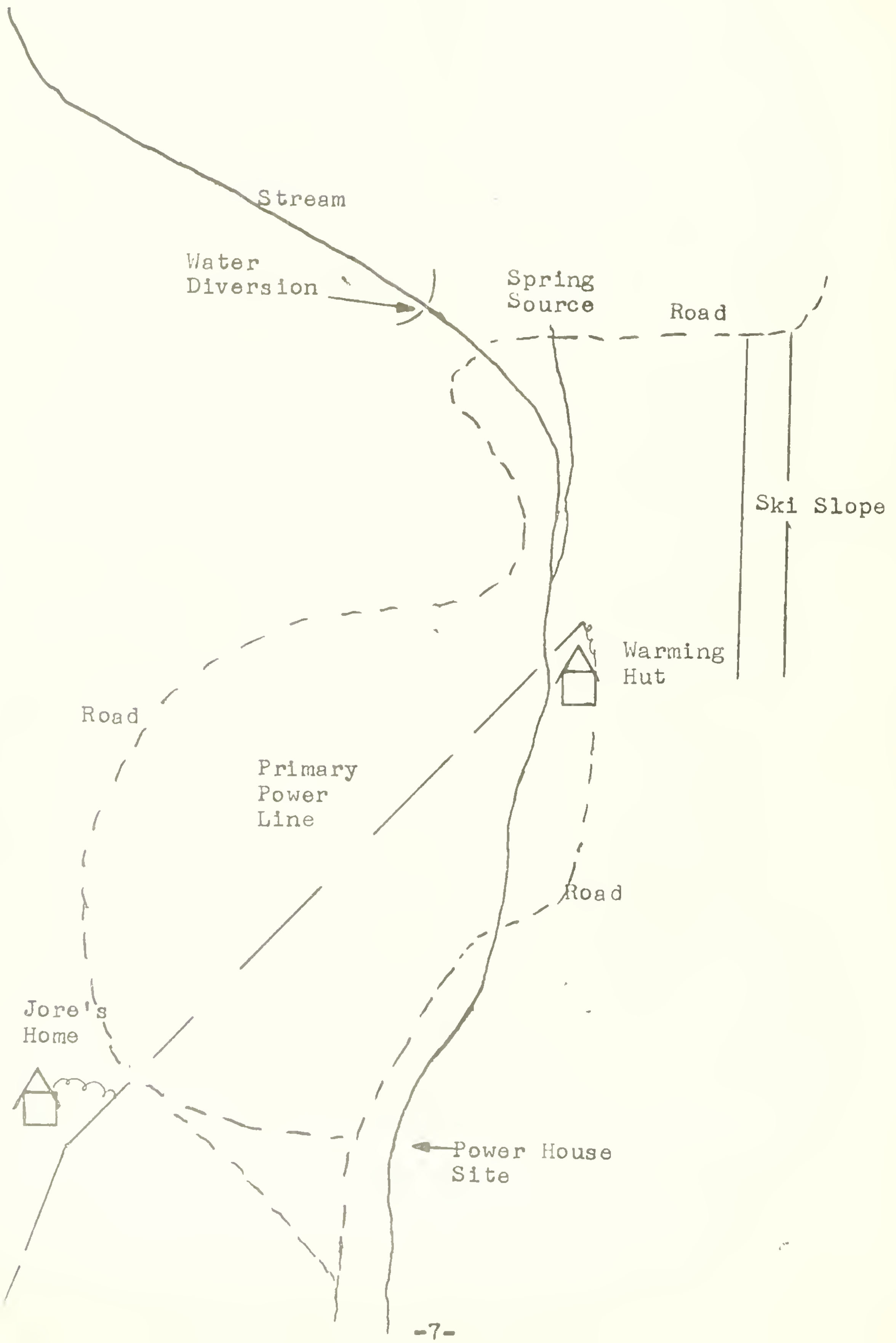
The above "no loss" power must be reduced by the following:

1. Flow at low water
2. Head loss due to penstock pipe friction
3. Turbine efficiency
4. Generator efficiency
5. Transformer losses
6. Transmission line losses.

SUMMARY

Electricity is presently on site. The potential of this site is far in excess of of the maximum generating capability the Renewable Energy Bureau has in mind for demonstration of small hydroelectric projects. There is no question but it is feasible to develop this site. This project appears better suited for private enterprise than DNRC funding. If I were Mr. Jore I would contact private engineers to measure the flow of water during the year to document potential power. The low water flow of 50% of the June measurement is suspect. The area is traditionally significantly lower. Even at the probable low water flow, the potential is probably in excess of 200 KWs delivered on line, with proper design.

Merle B. J e Property
N½ SW¼ S27 T20 R19



ENGINEERING REPORT

To

Renewable Energy Bureau
Energy Division
Department of Natural Resources
and Conservation
32 South Ewing
Helena, Montana 59620

Prepared by:

Richard G. Wrench
295 Highland Drive
Kalispell, Montana 59901
Phone: 257-8575

Contract No. 650-810
Effective Date: 5/6/81
Contract Amount: $8,500.00

Nature of Contract

Performance of feasibility studies
and system design analysis at four
potential microhydro sites

Report on:

Orlena Barnard
1395 Swan Highway
Bigfork, Montana 59911
Phone: 837-4423

"Hydro Power Demonstration Project
For Private Residential Use."

Submitted

Richard G. Wrench

Recommendation: Based on data provided by grantee, the project is not feasible. Repeated attempts to contact the grantee have proved unsuccessful. Sufficient electrical power exists in the area. Unless grantee can be contacted and a feasibilty study completed, funding should be denied.

General Comments

The site proposed is approximately 8 miles east of Polson, Montana. The site is bordering State Route # 35, and is located within the Flathead Indian Reservation. No actual engineering measurements have been conducted at the site. Orelena Barnard has been sent many letters requesting she get in touch with me or the Renewable Energy Bureau. There has been no response of any kind to any correspondence. I telephoned her continually, at all times of the day and evening. I contacted the telephone company to see if the phone was in working order & was informed it was. I contacted the sheriff and the police to see if they had any information. They did not. I called every Barnard in the telephone book it inquire if they knew of her. They had no information. On the premise that she was away & someone was collecting her mail I wrote a message on the outside of the envelope " to whomever is collecting Orlena Barnard's mail: have her get in touch with me or the Renewable Energy Bureau immediately as she was in danger of loosing her grant." I made repeated trips to her residence to try and make personal contact with her. I left messages in the door. A check of the mail box & newspaper box showed no mail and no paper. Vehicles were parked in the driveway. There was no response to the door. The grounds appeared to be well maintained and not deserted. Finally, I went to the area of the site. From the information in her proposal the general location of the proposed site can be ascertained. The project is located in Township 23 North, Range 19 West. It would appear the project was traced from a government topographical map. Matching the map in her proposal with a comparable government map, the area, but not the exact site was located. It is just off a paved State highway. Electrical power is currently accessible in the area. Preliminary conclusion is that power could be provided by the utility in the area for a fraction of the cost requested in her proposal. This is just an opinion, as the exact site would have to be investigated and priced by the utility company. On June 19, 1981 I received a letter from Mrs. Sandra Chapman, presumed a neighbor, 1377 Swan Highway, Bigfork, Montana, stating she had gotten in touch with Orlena Barnard. She said she was in Alaska and would be home in about two weeks.

Electrical load analysis

Orelena Barnard states a 1,350 square foot residence will be constructed on the site in the near future. Electricity will be the primary source of power. The power generated from the system is to be the source of electrical power. She desires to heat the home with electricity in the winter and to power an irrigation pump in the summer.

Assuming the electrical demands are typical of those in the average residential home, and similar to the service observed in Barnard's current residence the following should be representatitive of the anticipated power load.

Domestic needs	30 KW peak 40 KWH each 24 hours 1,200 KWH each month 14,400 KWH each year
Electrical heating *	20 KW peak 120 KWH each 24 hours in January 3,600 KWH January heating 21,557 KWH Annual heating load

Combining domestic and heating needs, the following load summary is estimated for Orlena Barnard

30 KW peak power required, without electric heat
50 KW peak power required, with electric heat.
1,200 KWH required each month, without electric heat
14,400 KWH required each year, without electric heat

35,957 KWH Required each year, with electric heat
4,800 KWH required in January, with electric heat
4,246 KWH required in February, with electric heat
3,763 KWH required in March, with electric heat
2,894 KWH required in April, with electric heat
2,299 KWH required in May, with electric heat
1,782 KWH required in June,with electric heat
1,377 KWH required in July, with electric heat
1,472 KWH required in August,,with electric heat
2,095 KWH required in September, with electric heat
2,903 KWH required in October, with electric heat
3,798 KWH required in November, with electric heat
4,520 KWH required in December, with electric heat.

* The BTUs required are those of a typical new construction home using 3½ inches of fiberglass insulation in the walls, and 6 inches in the ceiling, for the type home typical in the area.

SPECIFIC DATA AVAILABLE

Orlena Barnard indicated the staff from the DNRC's Technical Assistance Program, TAP, measured the available head and flow of the springs as follows.

Upper springs: 18 CFM @ 220 ft. head

Lower springs: 7CFM @ 180 ft. head

Apparent penstock distance: 1,200 feet

No loss power calculation as follows:
Assume 25 CFM @ 180 feet head

$$\frac{25\ (\text{CFM}) \div 60\ (\text{sec}) \times 180\ (\text{ft. head})}{11.8} = \text{Power in KW @ no loss}$$

$$\text{KW} = 6.3559$$

Assuming a 6 inch PVC would suffice based on proposal data from Bill Kitching, of Small Hydroelectric Systems, possible supplier, 4 feet per 1,000 foot of head loss would result.

Head loss of 4.8 feet would be expected.

The no loss theoritical power must be reduced by the following:

1. Flow at low water
2. Head loss due to penstock friction
3. Turbine efficiency
4. Generator efficiency
5. Transformer losses, if any
6. Transmission line losses

Losses are computed as follows:

Flow at low water: There is no information available. The proposal indicates the springs flow all year, but no flow variations. Assume a 30% reduction at low water, as the springs in that area generally produce without major variations.

Head loss due to penstock friction: 4.8 feet, per above.

$$\frac{25 \div 60 \times (180 - 4.8)}{11.8} = \text{Power in KW} = 6.186\ \text{KW}$$

equals 6.186 KW effect of penstock friction
x0.7 effect of low water flow
4.33 KW
x0.8 effect of turbine efficiency
3.464 KW
x0.85 effect of generator efficiency
2.9444 KW Probable average useable power

POWER AVAILABLE 2.9444 KW, round off to 3 KW constant power

Power generated peak	3 KWs	
Power generated each 24 hours-	72 KWH	
Power generated each month	2,160 KWH	
Power required peak, no heat	30 KWs	) no electric heating
Power required average, 24 hr	40 KW	)
Power required peak	50 KWs	) heating & domestic
Power required average, 24 hr	160 KWH	)

Conclusion:

It is not possible to heat the home with the power generated. The average non heating 24 hour power is less than the average power produced. It is therefore possible to store the electricity generated in batteries on a constant 24 hour basis. An inverter would be required to develop peak power on demand. The system then must be analyzed on the basis of storage.

BATTERY STORGAGE ANALYSIS

A bank of lead-acid, deep cycle batteries will be required. The voltage of the battery bank will depend on the specific inverter selected. for the purposes of analysis assume 18 12 volt batteries in series, producing 216 volts D.C. The first step is to size the amp hour capacity of each of the 18 batteries. This is computed as follows.

30 KW, 30,000watts, is the peak power required for Orlena's home. 18 batteries in series produce 216 volts.

30,000 (watts) ÷ 216 (volts) = 138 (amps) ohm's law

To produce 30 KW of power, a bank of 18 batteries, connected in series, would have to produce 138 amps of current flow. Since the batteries are in series, 138 amps would be flowing through each. Each battery is 12 volts. The power per battery is then computed as follows:

138 (amps) x 12 (volts) = 1,656 watts ohm's law

Each 12 volt battery must deliver 1,656 watts to provide the 30 KWs required at peak power. Sears, type 48 battery specifications, indicate it will supply 262 watts for 205 minutes. It will supply 6,720 watts for 30 seconds. Assume the battery can safely discharge 25% of its capacity without seriously effecting its life. Further assume the peak power will be required for one hour. The requirement, per each 12 volt battery, is to supply 1,656 watts for 60 minutes, and only discharge 25% of its capacity. 3.316 hours (205 minutes divided by 60 minutes) at the rate of 262 watts per hour is the specifications of the Sears, type 48, battery. 3.316 (hr) x 25%(desired discharge) equals 0.854 hours. The single battery could produce 262 watts for 0.854 hours and consume only 25% of its capacity. 1,656 watts required, divided by 262 watts provided per battery, equals 6.32 batteries. Therefore, 6.32 batteries connected in parallel, would produce 12 volts, at 1,656 watts for 0.854 hours, and consume 25% of their capacity. 1.0 (desired hour of capacity) divided by 0.854 (hours of capable production) equals 1.171. Multiplying 6.32 batteries times 1.171, 7.4 batteries are required. If it were possible to have 7.4 Sears type 48 batteries in parallel, they would produce 1,656 watts for one hour and consume 25% of their capacity. Rounding off the 7.4 to 8, the battery design now becomes 8 Sears type 48 batteries connected in parallel to form a bank. 18 of these banks will then be connected in series. A total of 144 batteries are required. They will produce 30 KW for 1 hour & consume 25% of capacity

The system' major components would be costed as follows:

Inverter @ 30 KWs 220/110 VAC	$12,000.00
1,200 feet of 6 in, PVC pipe at $5.00 ft	$6,000.00
144 batteries @ $50 ea	7,200.00
Controller	3,000.00
Turbine/generator	7,500.00
Valves	150.00
Concrete 10 yds @ $55 yd	550.00
Lumber, rebar, misc	350.00
Equipment	
Back-hoe 40 hrs @ $80	3,200.00
Loader 20 hrs @ $40	800.00
Salaries	
Site preparation 80 hrs @ $5	400.00
Instalation of pipe 20 hrs @ $5	100.00
Installation of turbine/generator	100.00
TOTAL	$41,350.00

Bringing in public power

The public utility is close by. The cost to bring in power is $2.00 each foot of distance covered, plus $1.50 each mile the crew has to travel each day

Polson to site, 16 miles round trip @ $1.50	$24.00
Assume 1,000 feet from utility to site @ $2.00/ft	2,000.00
Total	$2,024.00

SUMMARY

Altho the site has yet to be surveyed, it is assumed the staff from DNRC gathered accurate head & flow data. If this is the case, the herein analysis should be within the boundries of reasonable limits. Orlena Barnard indicated a desire for automatic switching equipment to the utility grid for periods of insufficient power.As the site could generate only 3 KW, and the needs are for 30 KW peak, the switching would occure constantly. Switching equipment is new, unknow as far as long term reliability & safety. The cost of such equipment would be an additional ten to fifteen thousand dollars above the $41,350.00 estimated for the project. The only possible system is the battery storage designed & priced. There is still the unknown problems of installing a pipeline under a major State highway. Since the estimated price of the system is $41,350.00, and the cost of bringing in power is $2,024.00, it does not appear to be a prudent expenditure of public money. There is no home heating possible with the power available. For these reasons, the project does not appear feasible and funding is not recommended. Should DNRC's staff' measurements of head & flow be of by a factor of 10, extremely unlikely, then the project may enter the realm of feasibility. The total cost would not change significantly, however.

ABSTRACT & SUMMARY OF FINDINGS

Ted Plaggemeyer, brother of Louis & Jack Plaggemeyer, requested the Energy Division, DNRC, study a canal & falls, flowing through the Plaggemeyer's property, called the Six Shooter Ranch Company, to determine its hydroelectric generating potential. The Plaggemeyer brothers desired to both use and sell the electrical power generated by the project.

The site was visited September 20, 1981. All engineering measurements and requisite data were taken at the time. Subsequently, additional information was requested and received. The site appears to be an ideal technical place to develop a hydroelectric generating project. A canal flows water approximately 5 months each year. The water drops 37½ feet through a vertical water fall. Primary electrical power lines are within 600 feet of the site. The site is conservately capable of developing 65 KW of useable electrical power 24 hours a day for the five months of current flow. Both Plaggemeyer brothers live and work on the ranch. Ownership dates back to the orgional homestead rights of deed. The ranch owns the water rights,& there is no indication of any reason why permits could not be issued.

Access to the site is through private property, posted with no trespassing signs. The last part of the access is through a creek canyon & a clay roadbed. Viewing by the public is problematical. The water flows from the North Fork of the Big Timber Creek, and is consumed by the water rights users in its entirety. There is no return channel. Mr. Louis Plaggemeyer is building his own new home in the immediate vicinity of the potential site. It is quit obvious Louis Plaggemeyer is a man of great cabability & could construct the project with a minimum of proper engineering supervision.

Two basic design options were examined. The first was to generate power and sell it to the utility company. This was further sub-divided into the 5 months the water currently runs, and on the assumption a means could be found to dispose of the water, on a 12 months basis. While technically an ideal site to generate power, selling it to the power company is extremely non cost-effective & is not feasible for that reason. The cost of $84,025 would return only $4,271 to $5,513, while the expected annual interest on construction costs would run between $10,083 & $15,124. These are the 5 month figures. On a 12 month basis, the project would be expected to return $10,020 to $12,980, with the same construction interest costs. On a 12 month basis the return is essentially equal to the interest. Additionally, the cost of providing a disposal channel will raise both construction costs & annual interest payments. On cost vs benefit, this approach is not cost-effective. If,however, matching funds were available & a low cost diversion of the water disposal were available, the project could be cost-effective. This approach should be pursued by the Six Shooter Ranch Company.

A second approach was to generate power and consume it on the premises. This involved generating power on the average consumption rate, storing it in 144 batteries, & having an electronic inverter provide house power when needed. This approach is extremely non cost-effective & therefore not feasible on either a 5 or 12 month basis.

GENERAL COMMENTS

The site investigated is called the Six Shooter Ranch Company. It is located several miles off Highway 191, eight miles North of Big Timber, Montana. Access is via seasonal,private, & unimproved roadbed. There are no trespassing signs posted throughout. Access to the actual site requires passing through a creekbed canyon and a clay road bed. The access is mentioned, as, if the site were to be developed with Bureau funds, public viewing would be problematical during summer & improbable during winter & spring.

The Six Shooter Ranch Company is a Montana Corporation, closely held, by the Plaggemeyer brothers. Ownership dates back to the orgional homestead rights of the Plaggemeyer family. Mr. Louis Plaggemeyer is building a new home, his personal residence, a few hundred feet from the potential site. His brother,Jack Plaggemeyer, lives approximately ½ mile away. Both brothers, Louis & Jack Plaggemeyer, live on and work the ranch. A third brother, Ted Plaggemeyer, lives in Helena. Being aware of the Bureau's objective to promote the development of microhydro power production in the state by establishing demonstration sites, Ted Plaggemeyer intervened in his brother's behalf. He requested a study be authorized to determine the potential of the canal & falls located on the Six Shooter Ranch Company lands.

The site was visited September 20. 1981. The flow of water and elevation measurements were taken, along with requisite engineering data required to conduct a feasibility study. The site is served by Park Rural Electric Cooperative, out of Livingston, Montana. Primary power, with sufficient capacity to accept the power generated by the site, is in place within 600 feet of the site of a potential power house.

The Plaggemeyer brothers do not have a well defined utilization of the power that could be produced. They would like to either use it, sell it, or both. Consequently, this study will examine all reasonable options.

The water comes from the North Fork of the Big Timber Creek, approximately 1½ miles away from the site. The water is diverted by a ditch rider, who subsequently records the flow each month in the County Court House records. The water is available approximately five months out of each year. During exceptionally dry years, the flow dries up for a maximum period of two weeks. The volume of water is consumed by the water right holders in its entirety. It does not flow back into any channel or stream bed. The site consists of a channel flowing through a rock bed cut in the side of a mountain. It then drops vertically 37½ feet, in a waterfall, where it continues to flow. The Six Shooter Ranch Company owns the necessary water rights to the water use.

Louis Plaggemeyer states the Ranch lands are not the site of Indian ceremonial, burial grounds, or any established useage that would preclude the isuance of permits. The canal is devoid of fish.

SPECIFIC DATA GATHERED

The canal was measured in 4 different places and averaged.

Case # 1.

Width: 13 ft-6in   13.5 ft

Depth measurements (all in inches)
5,6½,7 3/4,8½,10,9¼,10,9,9½,9½,10,9 3/4,9 3/4,10,9,7½.
Average: 8.828 inches, 0.7356 feet.   0.7356 ft

Time measurements for float to cover measured distance.
All measurements were in seconds. Float was kiln dried special wood, weighted to submerge two-thirds its height. A distance of 100 feet was measured out on the canal banks. 10 floats were measured to determine the time, in seconds, each took to traverse the 100 feet. This time was used for each of the four cases to determine flow.

Flow distance: 100 feet

Time measurements: (all in seconds)
19.5,25.0,24.0,24.4,26.5,27.5,25.0,23.0,25.2,24.95
Average 24.485 seconds

Case # 2.

Width: 13 ft-2in   13.1666 ft

Depth measurements (all in inches)
6½,8½,9½,11,10½,10½,10½,10½,11,10½,9 3/4,10,10,7 3/4,7,6½.
Average: 9.375 inches, 0.78125 ft   0.78125 ft
Flow distance: 100 feet
Flow time: 24.485 seconds

Case # 3.

Width: 13 ft-0in   13.00 ft

Depth measurements (all in inches)
5,7½,8,10½,11,11,11,11½,10,10,10,10½,10,9¼,8 3/4,8 3/4,8 3/4.
Average: 9.5 inches, 0.791666 ft   0.791666 ft
Flow distance: 100 feet
Flow time: 24.485 seconds

Case # 4.

Width: 16 ft-0 in   16.00 ft

Depth measurements (all in inches)
4 3/4,5,6,7 3/4,8,8½,8¼,9½,9½,8½,9,9,8,7¼,7,6,5½,4 3/4.
Average: 7.34722 inches, 0.6122685 ft   0.6122685 ft
Flow distance: 100 feet
Flow time: 24.485 seconds.

Calculation of water flow volume.

The following formula was used to determine flow:
The width of the creek, in feet, times the creek depth, in feet, times the distance the float travels in one minute, times the constant 0.8, equals the number of cubic feet of water flowing each minute.

Summary of the four measurements

Case #	Depth	x	Width	x	Distance/time travel	x	Const	=	CFM
Case 1.	0.735677	x	13.5	x	(100 x 60 ÷ 24.485)	x	0.8	=	1,946,9825
Case 2.	0.78125	x	13.16	x	(100 x 60 ÷ 24.485)	x	0.8	=	2,016.5395
Case 3.	0.79166	x	13.00	x	(100 x 60 ÷ 24.485)	x	0.8	=	2,017.5599
Case 4.	0.61226	x	16.00	x	(100 x 60 ÷ 24.485)	x	0.8	=	1,920.4499

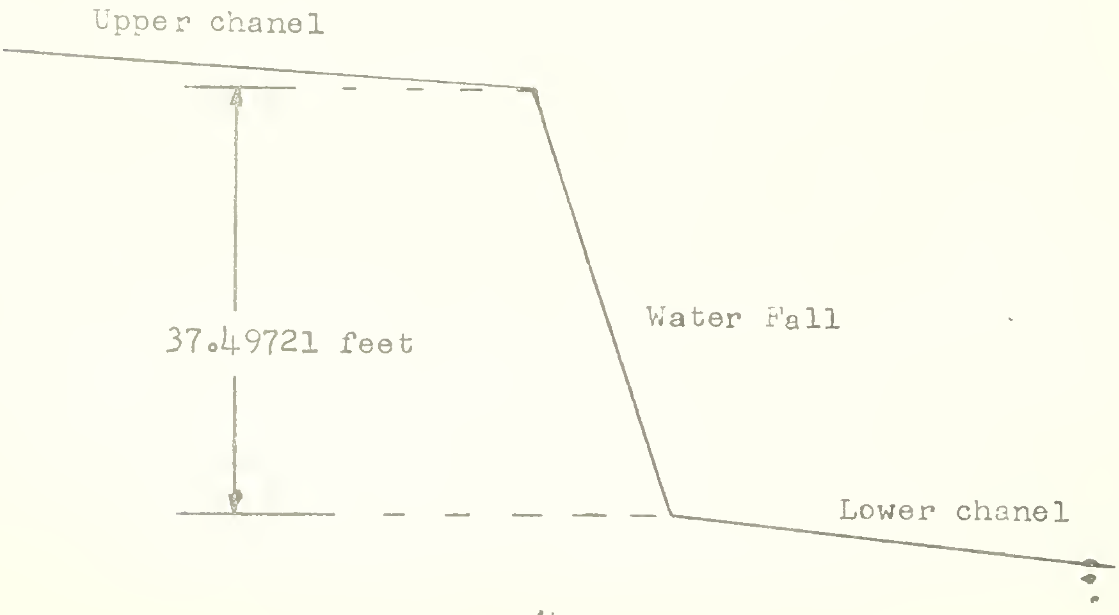
The average of the four cases is 1,975.3829 CFM. Since the power calculations require cubic feet per second, the above average is divided by 60 (seconds).

1,975.3829 CFM ÷ 60 = 32.923048 CFS

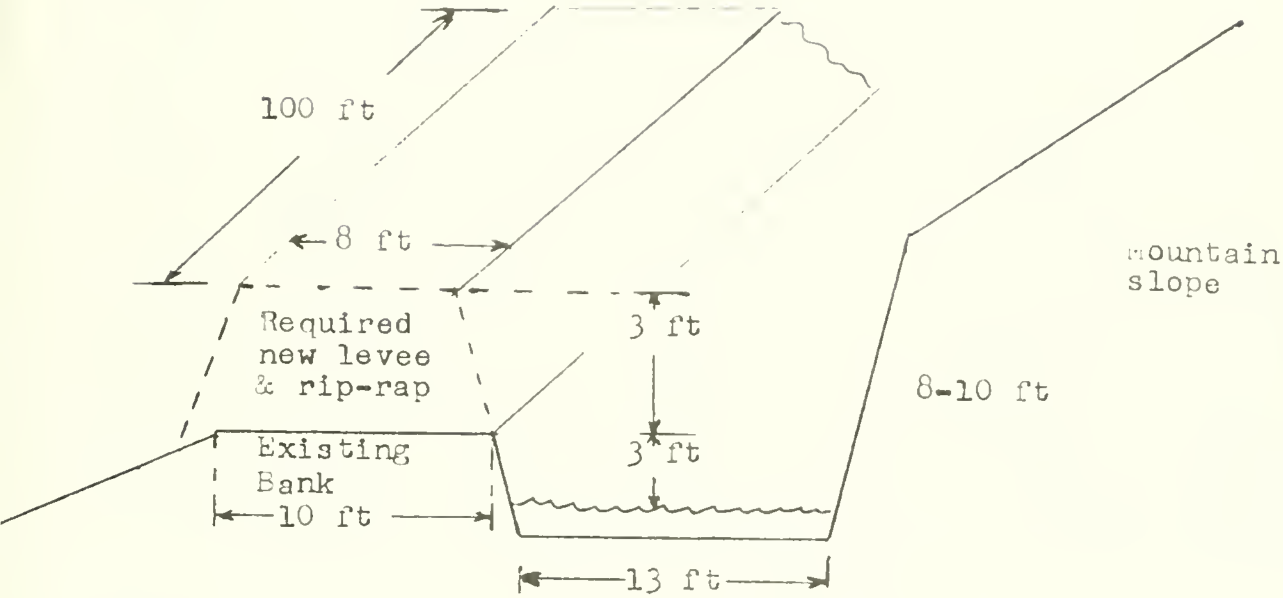
The flow of water on 20 September, 1981 was: 32.923048 CFS

Elevation measurements

A site was selected below the falls for a power house. A "Keuffel & Esser, K & E," professional surveying transit was used, along with a calibrated survey rule x steel tape, to determine elevation. The results are shown below.



The upper chanel and potential dam site is shown below.



Cross section view

This is a good place to point out that approximately 100 feet of additional fill would be required on the downhill bank. The creek side would require rock rip-rap to protect the bank from water erosion. The stream chanel is cut through a shale rock formation, showing excellent historic stability.

POWER CALCULATIONS

The following formula is used to determine the "no loss" power:

$$\text{Power, in kilowatts} = \frac{\text{Cubic foot water flow} \times \text{head in feet}}{11.8}$$

Flow: 32.923048 CFS
Head: 37.49721 feet

$$\text{Power, in KW} = \frac{32.923048 \times 37.49721}{11.8}$$

Power is therefore: 104.62054 Kilowatts.

It must be pointed out that this is no loss potential power, and must be reduced by the turbine efficiency, generator efficiency, transformer & line losses, to determine useable power.

Before the system can be designed and a power level determined, the variation of water flow must be determined. It is desirable to design the system so that a constant flow of water is available. Excess water would be allowed to spill over during periods of high water.

Fortunately, the monthly flow of water has been recorded by the ditch rider each year. The following table is the average of nine years recorded data.

Month	Recorded flow (Miner's inches)	÷ 40 equals **	Cubic feet/second CFS	
January	Zero	÷ 40 =	0	
February	Zero	÷ 40 =	0	
March	Zero	÷ 40 =	0	
April	Zero	÷ 40 =	0	
May	1,589.25	÷ 40 =	39.73125	CFS
June	1,840.66	÷ 40 =	46.0165	CFS
July	1,788.33	÷ 40 =	44.70825	CFS
August	1,536.71	÷ 40 =	38.41785	CFS
September	* Zero	÷ 40 =	*32.92048	CFS
October	Zero	÷ 40 =	0	
November	Zero	÷ 40 =	0	
December	Zero	÷ 40 =	0	

* While the September flow was not recorded, water was measured on September 20, 1981 as representative of September flow.

** 40 miner's inches equal one cubic foot of water flow per second.

Power calculations, continued:

Using the formula on page five, the theoretical, no loss power for each of the months the water flows is shown below.

Month	Water flow	Theoretical power
May	39.73125 CFS	126.65516 KW
June	46.0165 CFS	146.22799 KW
July	44.70835 CFS	142.07104 KW
Aug.	38.41785 CFS	122.08153 KW
Sept.	32.92048 CFS	104.62054 KW

The low water, average flow would appear to occur in September of the year. To account for seasonal fluxation, a conservative, no loss power of 100 KW will be assumed for design purposes. This power is reduced as follows, to derive the useable power.

100 KW theoretical, no loss power
x 0.8 Turbine efficiency
x 0.85 Generator efficiency
x 0.95 Transformer & line losses
64.6 KW useable power

Rounded off, assume a conservative 65 Kilowatts of useable power.

If the system is to be designed and built, the low water period, occuring late in the season, should be the basis of design. A constant head and volume of water should be available to the generating equipment at all time. Excess water will be allowed to spill over the dam spillway at times of high water. The following table will show the effect of designing the site for the low water measured in September and allowing the spilling of the rest during the rest of the year.

Month	Theoretical power	Useable power * see note	Water over spillway if designed for Sept. flow
May	126.65516 KW	81.8 KW	6.81 CFS
June	146.22799 KW	94.5 KW	13.1 CFS
July	142.07104 KW	91.8 KW	11.8 CFS
Aug.	122.08153 KW	78.9 KW	5.5 CFS
Sept.	104.6205 KW	67.6 KW	0.0 CFS

Example: If the site were designed to use the flow of water available in September, 6.81 CFS of water would be flowing over the spillway in May. The May useable power is 81.8 KW, however, since the system is designed to produce a constant 67.5 KW, with the excess flowing over the spillway, the useable power will be constant from May to September at 67.6 KW.

* Note: The useable power is shown here for interest only. This number shows how much power is available if the system were to be designed for this month, instead of the low water month.

Summary of useable power

For purposes of costing and planning assume 67.6 KW of useable power will be available 24 hours each day during the season when the water is available. If the system is to be actually built, a more conservative design number would be 65 KW.

DESIGN & COSTING OF THE SYSTEM

There are two possible uses of the electrical power generated. The first is to sell the power to the utility company. The second is to generate and consume the power on the premises. There is obviously a third possibility, where power is both sold and consumed. From a cost of construction consideration, this is the same cost of construction as selling power to the utility.

The system will be costed as two separate designs.

Design # 1. Sell the electrical power generated to the utility utility company. The generator would be connected to the primary power lines of the utility company's transmission lines through special equipment that combines both safety and matching of the electrical characteristics of the generator with the requirements of the utility grid. A meter would indicate the power sold. The service to the house would be unchanged,

Probable cost to sell generated power to the utility co.

Owner built dam and spillway	$2,500.
Owner built trash rack	150.
Water flow gate, owner installed	500.
Penstock: 4 ft diameter steel, low pressure	800.
Owner built power house	2,000.
Switching & safety equipment	10,000.
Land fill & rip-rap, owner installed	1,500.
Lightening arrestors, 2 each @ $100 ea.	200.
Transformer	500.
Primary underground wire: 700 ft @ $1.25 ft	875.
Turbine package per attached Leffel bid	61,900.
Control panel & misc. (estimated)	3,100.
Estimated costs	$84,025.

This cost, $84,025., is based on the assumption that Mr. Louis Plaggemeyer will perform much of the work himself, under proper engineering supervision. In my meeting with him, it was my impression he was a man that was extremely capable. Told what to do, why, & what to be concerned about, I have no doubt he could complete the project without engaging an engineering construction firm experienced in hydroelectric construction projects. The project would require additional bidding if the job were to be completed by an engineering construction firm. The price would be at least twice the above estimate in such a case.

Design " 2.Generate & consume the power on the premises.
In design # 1., all the electrical power generated, entered the power lines and was consumed someplace in the system. When power was needed by the home it was drawn from the lines and used as and when needed. To generate all the electrical power required in a modern home,requires generating electricity at the average rate it is consumed, and then storing it in some manner until a peak demand is required and then supplying it. This is done by selecting an average monthly consumption of electrical power, specified by the number of kilowatt hours consumed. Assuming a 30 day month and 24 hour day, the number of kilowatt hours used is divided by 720 (30 days x 24 hr) to arrive at the average hourly rate of electrical power consumption. For example, if a family consumed 3,300 kilowatt hours of electric power in 30 days, 4.583 kilowatts would be consumed each hour,on the average, (3,3000 divided by 720 equals 4.583). In this example a generator providing 4.584 kilowatts of power each hour would produce all the electrical power required by the family. Unfortunately, average power can not provide all the power necessary at any one point. For example the average home may require 30 kilowatts at any time. This is why the average power must be stored and made available when needed.

For quality of life,a storage system must be designed in such a manner that the electrical needs of the home are supplied when required in essentially the same manner the electrical utility supplies power to the home today. The basic concept for the

Six Shooter Ranch Co. would be to store the electricity in deep cycle batteries as it is being generated 24 hours each day. When electrical power is required, the DC power in the batteries is automatically converted into the 120/240 volt AC power needed by the home. The occupant of the home is unaware of the source of power. An electronic inverter changes the battery power to house power on demand. The system is designed as follows.

Electrical load analysis

I would assume Mr. Plaggemeyer has the following:

Clothes dryer	5,500 watts
Dishwasher	1,200
Small power tools	250
Freezer	440
Garbage disposal	445
Iron	1,100
Range	9,200
Refrigerator	600
Television	350
Toaster	1,100
Washing machine	500
Water heater	5,500
Oven	8,000
Coffee maker	1,000
Lighting	1,200
	36,385 watts

While the details may vary, it is reasonable to expect a home to require 30,000 watts, or 30 kilowatts at any time during the day. The following power summary is reasonable.

30 KWs of peak power required any time
60 Kilowatt hours consumed each 24 hours
1,800 Kilowatt hours consumed each month.

This will be the basis of designing a storage system. The exact ratio of the actual power consumed to the above figures can be used to change the size, & subsequent cost, of the final system The numbers I am using are very close the the power actually consumed by Mr. Louis Plaggemeyer.

60 KW hours consumed each 24 hours averages 2.5 KWH each hour. With 2.5 KWs consumed each hour, on the average, it is good engineering practice to design a system capable of producing twice this power, or a 5 KW system. It will last longer & be significantly more reliable. It is also cheaper in the long run. A typical lead-acid battery will last 10 years if not allowed to discharge significantly.

Battery design: Battery storage is difficult to predict even under ideal conditions. A large number of batteries will be required. The volume, plus the requirements of the National Electrical Code, dictate a special facility to house the batteries.

The first step is to determine the number of batteries required. Several batteries will be in parallel for capacity. Each of these parallel banks of 12 volt batteries will be connected in series. Imagine 18 very large 12 volt batteries connected in series. This grouping of batteries will product the voltage and the power required by the peak power demands.

30 KW, 30,000 watts, is the assumed peak power required by Louis Plaggemeyer. 18 batteries connected in series will produce 216 volts (12 volts times 18 equals 216 volts).

30,000 (watts) ÷ 216 (volts) = 138 amps Ohm's law

To produce 30 KWs of power, a bank of 18 batteries in series would have to provide 138 amps of current flow. Since the batteries are in series, 138 amps would be flowing through each battery. Each battery is 12 volts. The power for each battery is then computed as follows:

138 (amps) x 12 (volts) = 1,656 watts

Each 12 volt battery must then deliver 1,656 watts to provide the 30 KWs required by Plaggemeyer at peak power. Sears type 48 battery specifications indicate it will supply 262 watts for 205 minutes. It will also supply 6,720 watts for 30 seconds as well, which will help in the moments of excess & unexpected power surges. Assume the battery will be allowed to discharge 25% of its capacity. This is a reasonable discharge level to insure long life, as long as the battery is recharged in a reasonable time. The requirement then, for the individual 12 volt battery, is to supply 1,656 watts for the period of time the peak power is required. A very conservative time period would be an hour. (this much time would rarely be required) 3.316 hours, which is the Sears type 48 battery capacity (205 minutes ÷ 60). 3.316 hours x the 25% maximum amount of discharge equals 0.854 hours of discharge per battery. The individual battery would then produce 262 watts for 0.854 hours, and consume only 25% of its power.

Since each battery was shown to require 1,656 watts of power to produce the 30 KWs of peak power, 6.32 batteries (1,656 watts divided by 262 watts) would be required for a bank. 6.32 batteries connected in parallel would produce 12 volts and 1,656 watts of power for 0.854 hours, and discharge 25% of their power. Since one hour's time is desired the number of batteries must be multiplied by the ratio of increased time. 1 hour divided by 0.854 hours equals 1.171 time the 6.32 batteries equals 7.4 batteries. A total of eight batteries in parallel are then required to provide the capacity of the bank. Eighteen of these banks are then connected in series to complete the storage. 144 Sears type 48 batteries, or the equivalent, would then be required. They would be capable of providing 30 kilowatts of power for one hours time, while discharging 25% of their power. This completes the battery analysis.

Storage concept summary

A generator produces electrical power 24 hours a day at the average rate of consumption. In the case of Louis Plaggemeyer approximately 2½ KWs of average power has been consumed. It is assumed that approximately 30 KWs of peak power would be needed for periods up to one hour. To provide this power 18 banks of 8 batteries per bank, are connected in series, or a total of 144 batteries. An electronic inverter will provide the necessary house voltage and power on a demand basis, drawing power from the battery storage. By allowing the batteries to discharge a maximum of 25% of the power and then recharging, a life of up to 10 years can be expected. A separate storage facility to house the battery banks will be required by code and safety considerations.

Probable cost to generate & consume power on the premises

Owner built dam & spillway	$2,500.
Owner built trash rack	150.
Water flow gate, owner installed	500.
Penstock SDR 30/30 gravity sewer pipe	412.
Owner built power house	2,000.
Land fill & rip-rap, owner installed	1,500.
Lightening arrestors, 2 each @ $100 ea.	200.
Transformer	500.
Primary underground wire: 700 ft @ $1.25 ft	875.
* Generator/turbine package	15,000.
* 2,500 ft primary underground wire to Jack's house	3,125.
* Transformer for Jack's house	500.
* 144 batteries for Jack's house @ $50 ea	7,200.
* 30 KW invertor for Jack's house	24,000.
* Battery storage facility for Jack's house	3,000.
* Battery electrical connections & equipment, Jack's	3,500.
* Charging equipment, Jack's house	1,000.
144 batteries for Louis's house @ $50 ea	7,200.
30 KW inverter for Louis's house	24,000.
Battery storage facility for Louis's house	3,000.
Battery electrical connections & equipment, Louis's	3,500.
Charging equipment, Louis's house	1,000.
Estimated costs	$104,662.

The cost to generate the average electrical power required by both Jack & Louis Plaggemeyer, store it in batteries, & convert it into house power on demand is estimated to be $104,662.

* If power is generated & stored, etc., for Louis Plaggemeyer's home only, then the generator cost can be reduced by $5,000. & the cost of Jack Plaggemeyer's system, $42,325. reduced. The **total** cost of adding Jack Plaggemeyer to the storage system is $47,325 additional dollars. The cost to provide a battery storage system to supply Louis Plaggemeyer home is $57,337.

Cost summary of generating & consuming power on the premises

Provide power to both Jack & Louis Plaggemeyer	$104,662.
Provide power to Louis Plaggemeyer only	57,337.
Additional cost to add Jack Plaggemeyer	47,325.

Cost to benefit analyses of the design options

The following table shows the electrical power Jack & Louis Plaggemeyer have historically consumed. The right hand column indicates the cost of purchased power.

	Month	Power Consumed		Total Consumed	Total Costs @ 3¼¢/KWH		
		Jack	Louis	both families	Jack	Louis	Total
	Jan.	3,300 KWH	2,000 KWH	5,300 KWH	$107	$65	$172
	Feb.	3,300 KWH	1,800 KWH	5,100 KWH	$107	$58	$165
	March	3,200 KWH	1,600 KWH	4,800 KWH	$104	$52	$156
	April	3,100 KWH	1,400 KWH	4,500 KWH	$100	$45	$145
*	May	3,000 KWH	1,200 KWH	4,200 KWH	$97	$39	$136
*	June	2,900 KWH	1,200 KWH	4,100 KWH	$94	$39	$133
*	July	3,000 KWH	1,200 KWH	4,200 KWH	$97	$39	$136
*	August	3,100 KWH	1,200 KWH	4,300 KWH	$100	$39	$139
*	Sept.	3,200 KWH	1,400 KWH	4,600 KWH	$104	$45	$149
	Oct.	3,200 KWH	1,600 KWH	4,800 KWH	$104	$52	$156
	Nov.	3,300 KWH	1,800 KWH	5,100 KWH	$107	$58	$165
	Dec.	3,300 KWH	2,000 KWH	5,300 KWH	$107	$65	$172
nnual	Totals	37,900 KWH	18,400 KWH	56,000 KWH	$1,228	$596	$1,824
* 5 months nen water s running		15,200 KWH	6,200 KWH	21,400 KWH	$492	$201	$693

Summary of power consumed

Jack Plaggemeyer consumes 37,900 KWHs each year at a cost of $1,228
Louis Plaggemeyer consumes 18,400 KWHs each year at a cost of $596
The combined useage each year is 56,000 KWHs, for a cost of $1,824
During the five months the water is running in the canal a total of 21,400 KWHs are consumed for a cost of $693.

This consumption is based on the data supplied by Louis Plaggemeyer. The cost is on the assumption of 3¼¢ per KWH. Should the consumption or the cost change in the future, this table can be reconstructed. The resultant values can then be "plugged in" to the subsequent cost-effectiveness studies.

Cost to benefit/Cost-effective analysis

It must be pointed out, that while the Federal Government passed a law requireing the utility companies to purchase power, the law does not specify how much money they are required to pay. This issue is currently being debated at hearings before the Montana Public Service Commission. A decision is not expected until sometime in late 1982. One thing is for certain, what ever the price, it will be significantly less than what you are now charged.

The income expected &/or the costs saved will be shown for each design option discussed. While the water flows for only 5 months out of the year at this time, should the Six Shooter Ranch Company wish to consider taking the steps required to have the water flow 12 months out of the year, the resulting dollar effect will also be shown.

Design option # 1. Sell all generated power to the utility co.

Case A: Generate power 5 months when water flows.

67.6 KWs x 24 hours x 153 days will produce 248,227 kilowatt hours.

The following table indicates the income expected as a function of the price the utility company will pay for the purchased power. The price both Jack & Louis Plaggemeyer now pay for the consumption of their purchased power is subtracted from the income to arrive at a net income. Not knowing the source of funds to develop the system, the estimated cost of $84,025 is divided by the income, to indicate the number years required to recover cost. When the source of funds is identified, the interest costs must also be included in determining time to recover costs. The price per kilowatt hour shown in the left hand column range from what the utility companies currently charge their customers to the price some individuals are now either being paid or offered.

Price you would be paid per ea. KWH sold	Gross income paid for the five months you would be selling power	Less the $693 you now pay for your power	Net income you would receive for the five months	Number of years to recover your costs. $84,025 divided by net income
3¼¢	$8,067.	-$693	$7,374	11.4 years
3¢	$7,447.	-$693	$6,754	12.4 years
* 2½¢	$6,206.	-$693	$5,513	15.2 years
* 2¢	$4,965.	-$693	$4,271	19.6 years
1½¢	$3,723.	-$693	$3,030	27.7 years
1.1¢	$2,730.	-$693	$2,037	41.2 years
½¢	$1,241.	-$693	$548	153.3 years
1/10¢	$248.00	-$693	Loss	-----

* The best estimate of the eventual price you will be paid for the power you will sell to the utility company.

Summary of generating power & selling it to the utility company for the 5 months when the water flows.

Assuming you will receive 2 to 2½ cents for each kilowatt hour sold, you would expect to net between $4,271 & $5,513 each year in income. From this income the interest paid on the $84,025 would have to be deducted. As $4,271 represents 5.083%, and $5,513 is 6.561% of the $84,025 cost of the project, and the current interest charged on money is in the 12-18% range it is quite obvious the cost to develop this project is excessive when considering the return. The expected return for five months will be considerably less than the interest required on the cost. While the project is obviously quite feasible from a technical standpoint, it is not feasible from a cost-effective standpoint. It does not make good business sense to expend $84,025 to construct a project, when the return is between $4,271 & $5,513, and the interest on the principle costs will be between $10,083. (12% int.) & $15,124. (18% int.). The net loss would range between $5,812 ($10,083 int. - $4,271 income), & $9,611. ($15,125 int. - $5,513 income).

It is concluded, therefore, that while it is quite feasible to construct a hydroelectric project capable of generating 67.6 KWs 24 hours each day for five months, the project is not feasible from a cost-effective standpoint and should not be developed.

Case B: Generate power 12 months out of the year & sell all the power generated to the utility company. It is realized that there is currently no provisions for returning the water to the North Fork of the Big Timber Creek, or any other point of disposal. The cost of providing a means of returning the water to an appropriate channel must be added to the $84,025 cost of constructing the project and the following table recalculated.
67.6 KWs x 24 hours x 365 days will generate 592,175 kilowatts a year
The notes above the table on page 13 will also apply to this table

Price you would be paid per ea. KWH sold	Gross income paid for the 12 months you would be selling power	Less the $1,824 now paid for your power	Net income you would receive for the year	Number of years to recover your costs. $84,025 divided by net income.
3¼¢	$19,245	-$1,824	$17,421	4.82 years
3¢	$17,765	-$1,824	$15,821	5.31 years
* 2½¢	$14,804	-$1,824	$12,980	6.47 years
* 2¢	$11,844	-$1,824	$10,020	8.38 years
1½¢	$8,883	-$1,824	$7,059	11.9 years
1.1¢	$6,514	-$1,824	$4,690	17,91 years
½¢	$2,960	-$1,824	$1,136	73.96 years
1/10¢	$592	-$1,824	Loss	-----

* The best estimate of the price you will eventually be paid by the utility company.

Summary of generating power 12 months each year & selling it to the utility company.

Assuming you will receive 2 to 2½ cents for each kilowatt hour sold, you would expect to net between $10,020 & $12,980 each year. From this income the interest paid on the $84,025 cost of the project would have to be paid, and deducted. $10,020 represents 11.92% of $84,025. $12,980 represents 15.44% of $84,025. The current interest charged is in the 12-18% range. At 12% interest, the annual interest charge on the $84,025 cost would be $10,083; at 18% it would be $15,124. The income each year would then range between $10,020 & $12,980. The annual interest payments would range between $10,083 & $15,124. A 30 year payback period would require an over simplified $2,800 reduction of the principle each year, at a zero interest rate. As it will obviously cost money to provide a route for the water to be returned to a disposition channel, this option is not costeffective either. While this option is significantly more cost-effective than selling power for five months, it will pay only the interest on the principle. When the cost of disposing of the water is added onto the cost of the project, the income will not be sufficient to pay the interest on the overall cost. Should a no cost means to dispose of the water be found, and a very low interest source of money, or matching funds be made available, this approach could become cost effective. It is recommended the Six Shooter Ranch Company investigate this possibility.

Design option # 2. Generate & consume the power on the premises.

The following table indicates the dollars saved by generating power and consuming it on the premises. The dollars saved are those not paid to the utility company. The time to recover the construction costs is an oversimplified division of cost by dollars saved. To provide an indication of interest costs each year, the two right hand colums show annual interest required for the current interest.

Design Options	Cost of Construction	Dollars Saved ea year	Years to Recover Costs	Annual interest @ 12% payments	@ 18%
5 mo. Louis only	$57,337	$201	285 years	$6,880	$10,320
5 mo. both bro.	$104,662	$693	151 years	$12,559	$18,839
12 mo. Louis only	$57,337	$596	96 years	$6,880	$10,320
12 mo. both bro.	$104,662	$1,824	57 years	$12,559	$18,839

It is obvious that the dollars saved, compared to the total cost, & more specifically, the annual interest required on the construction cost, makes this option extremely non cost-effective, & therefore not feasible.

ABSTRACT & SUMMARY OF FINDINGS

The City of Bozeman requested the Energy Division, DNRC, study Bozeman Creek to determine the hydroelectric generating potential. The City desired to use the power to light its downtown buildings, sell excess power to the utility company, and utilize the site as a public demonstration of renewable energy at work.

Five sites were identified, and an engineering feasibility study conducted on each. The useable amount of electrical power was determined, the cost to construct the facility estimated, the cost to benefit ratio shown, and the practical aspects of each site discussed.

The sites, and a brief summary are shown below.

Site # 1. The existing diversion dam at the mouth of Bozeman Canyon.

Summary: The site is technically capable of producing marketable amounts of electrical power. However, it is neither feasible nor practical. Bozeman Creek is subject to uncontrolled period flooding, and seasonal high water flows. A new dam and extensive levees would be required just to generate power. Without flood control, the facility would flood & be destroyed each spring. Flooding would contaminate the city water supply. The estimated income is between $1,752 & $2,190. The cost is estimated to be $47,400.

Site # 2. The presedimentation settling basins

Summary: A one mile long pipe, capable of transporting the water from site # 1,with very little loss, would have to be designed and constructed. While it is technically possible to design & construct such a pipe, the cost would be prohibitive. The existing concrete pipe can not be used for a penstock, due to its frictional losses. The four mile distance to Hyalite is too long to be considered. Even if the pipe problem could be solved for a reasonable cost, the project is estimated to cost $206,768. The income is estimated to be $6,132 to $7,665. Due to the one mile distance between the water source and the generator, the site is not practical. The high cost of construction and the low income, makes it economically not cost-effective.

Site # 3. The municipal water reservoir.

Summary: A situation similar to the above site exists here. A two & one half mile pipe line would have to be designed and constructed. The existing concrete pipes are too old, too small a diameter, and too rough to be of use for a penstock. It would be a major engineering challenge to design & construct a 2½ mile long pipe that would function as an operational pipeline. Even if the pipe problem could be solved for a reasonable cost, the project is estimated to cost $429,620 to construct. The annual income would fall between $6,307 & $7,884. The site is not a practical one for consideration due to the 2½ mile long distance between the water source & the generating site. Further, it is definitely not cost-effective, due to the high construction cost and the low return.

Site # 4. Downtown Bozeman, adjacent to the new library.

Summary: The site is basically too shallow to be developed. It would be necessary to have both a positive flood control, which does not exist, and a long unsightly concrete channel and dam complex, to back up sufficient elevation of water for potential use. Even with a channel starting at the street upstream, only a couple of feet could be achieved. The site could produce "theoretical" power, but it would be extremely difficult to produce power practically. With only 2 feet of head, and no practical place to locate a powerhouse, it is simply not practical to try & develop this site. Any dam would cause extensive flooding each spring. The area is a flood plain. If absolute flood control measures were available, and a practical means of constructing a dam & generating equipment were also available, the site is estimated to cost $50,400 to construct. The annual income would be between $643 & $804. The site is neither practical nor cost-effective.

It is possible to design & install an undershot water wheel, capable of producing sufficient electrical power to have some lighting, such as Christmas tree lights.

Site # 5. Along the railroad tracks, from the trestle to the park.

From the trestle over Bozeman creek to a suitable generating site next to the City Park, is 2,100 feet. Over this distance the drop is only 15 feet, with most of that occuring next to the park. This is too shallow a slope & to far a distance to be practical for hydroelectric power development. Bozeman Creek flows through land so shallow, at this site, that it is not practical to build a diversion dam. All the water would have to be diverted to produce power. The City does not own the water rights to do this, & it is extremely unlikely the cost & time involved in acquiring them would be worth the results. If Bozeman Creek were diverted to the area of the City Park, the result would be to flood the densely developed area, or construct a new stream bed through the area. It would be a major engineering challenge to design & construct a 2,100 foot long penstock, capable of functioning as a penstock with only a 15 foot head. If such a project were constructed, the cost is estimated to be between $280,800 and $381,600. The annual income would be between $4,730 & $5,913. Additionally, the water would have to be pumped up hill to the railroad bed 10½ feet. To further complicate the problem, the railroad bed, rails & ties would be destroyed in the pipeline laying process. The ownership & use of the right(s) of way is unknown, & apparently not owned by the city. The site is not practical nor cost-effective for development.

STUDY APPROACH

The theoretical power each site would be capable of producing, as a function of volume of water flowing and the available head, is first determined. The losses due to penstock pipe friction, equipment efficiencies, etc. are used to arrive at useable power. Even tho the practical considerations may preclude feasibility, the site is costed & results presented.

GENERAL COMMENTS

Mr. Russ Heliker, Energy Planner for the City of Bozeman, requested The Renewable Energy Bureau, Energy Division, DNRC, conduct feasibility studies of selected sites on Bozeman Creek. The City wished to determine their potential for generating hydroelectric power. The City had just completed a new Public Library that derived some of its energy from renewable energy sources. It was hoped to have a public demonstration site, combining the renewable energy microhydro electrical generation potential of Bozeman Creek,with the existing new library. Subsequent to the library site, several others were added.

To provide the City of Bozeman a broad base,on which future planning decisions could be justified,all available potential sites were studied. Following, is a list of those examined.

Site # 1. The diversion dam at the mouth of Bozeman Canyon.

Site # 2. The presedimentation settling basins.

Site # 3. The municipal water reservoir.

Site # 4. Down town Bozeman adjacent to the new library.

Site # 5. From the railroad trestle over Bozeman Creek, along the railroad right of way, to the City Park.

Bozeman Creek has been the object of several water studies in recent time. Recorded data dating back to 1951 was identified and collated. This study is thus a compliation of all studies to date. A key, and most significant concern, is the fact that it was determined Bozeman Creek is subject to frequent and uncontrolled flooding. Unless, or until, a flood control means is incorporated at some future date, it is highly recommended no dams or other water impoundment schemes be considered, below the diversion dam. During these high water periods, the dam would be breached, and would most likely destroy the facility along with adjacent lands and improvements. Additionally, the slope of land,through which Bozeman Creeks flows,is generally to shallow for use as development of hydroelectric projects.

Along with determing current feasibility for hydroelectric power development, this study also provides a data base for future utilization of Bozeman Creek.

This study was made possible by funds supplied from the coal severance tax, through the Renewable Energy Bureau, Energy Division, DNRC, State of Montana.

USE OF THE POWER GENERATED

Mr. Heliker indicated that if the library site was feasible, it was the City's intent to use the power generated to help light several downtown City buildings. The excess nighttime electricity would be sold to Montana Power Company. Power produced from the other sites would also be sold to Montana Power Company.

Each of the five sites studied will be presented in its entirety, as a complete study report.

Site # 1. The diversion dam at the mouth of Bozeman Canyon.

SPECIFIC DATA GATHERED

Flow measurements

Four different sites were measured and averaged.

Case # 1. Width of the waterway: 14.0 feet
Depth measurements: (all figures are in inches)
6,9,10,9½,10,14,14,12,12,10,9½,9,8,7,7,7,7½,6
Average depth was 9.30555 inches, or 0.7754629 feet

Case # 2. Width of the waterway: 15.5 feet
Depth measurements: (all figures are in inches)
4,5 3/4,6,9,9½,9½,11¼, 12,11½,11,8½,7,9,6 3/4,6½,5¼
Average depth was 8.28125 inches, or 0.6901041 feet

Case #3. Width of the waterway: 15.5 feet
Depth measurements: (all figures are in inches)
7 3/4,9,8 3/4,9,8,8 3/4,10¼,8½,7,6,6¼,6¼,6,5¼,5
Average depth was 7.45 inches, or 0.620833 feet

Case # 4. Width of the waterway: 18.6 feet
Depth measurements: (all figures are in inches)
6,6,7,5,6¼,7,5½,6,6 3/4,7½,7,8,6,5,5 3/4,6,7,7,5,5,6,4,4,5,5,4
Average depth was 5.875 inches, or 0.4895 feet

Water velocity measurements

Float distance measured was 85 feet.
Float time: (all figures are in seconds)
28, 40, 38, 32, 37, 34, 30, 38 Average time: 34.625 seconds

Flow calculations

The following formula was used to calculate flow:
The width of the stream, in feet, times the depth, in feet, times the distance the float travels in one minute, times the constant, 0.8, equals the cubic feet per minute of flow.

The four cases are computed and averages as follows:

Case	Water Depth	x Width	x Distance Trav.	x K	= CFM
1	0.7754629 ft	x 14.0 ft	x (60 ~~x85~~ ÷ 34.625)	x 0.8	= 1,279.2615
2	0.6901041 ft	x 15.5 ft	x (60 ~~x85~~ ÷ 34.625)	x 0.8	= 1,260.4238
3	0.620833 ft	x 15.5 ft	x (60 ~~x85~~ ÷ 34.625)	x 0.8	= 1,133.9053
4	0.4895833 ft	x 18.6 ft	x (60 ~~x85~~ ÷ 34.625)	x 0.8	= 1,073.025

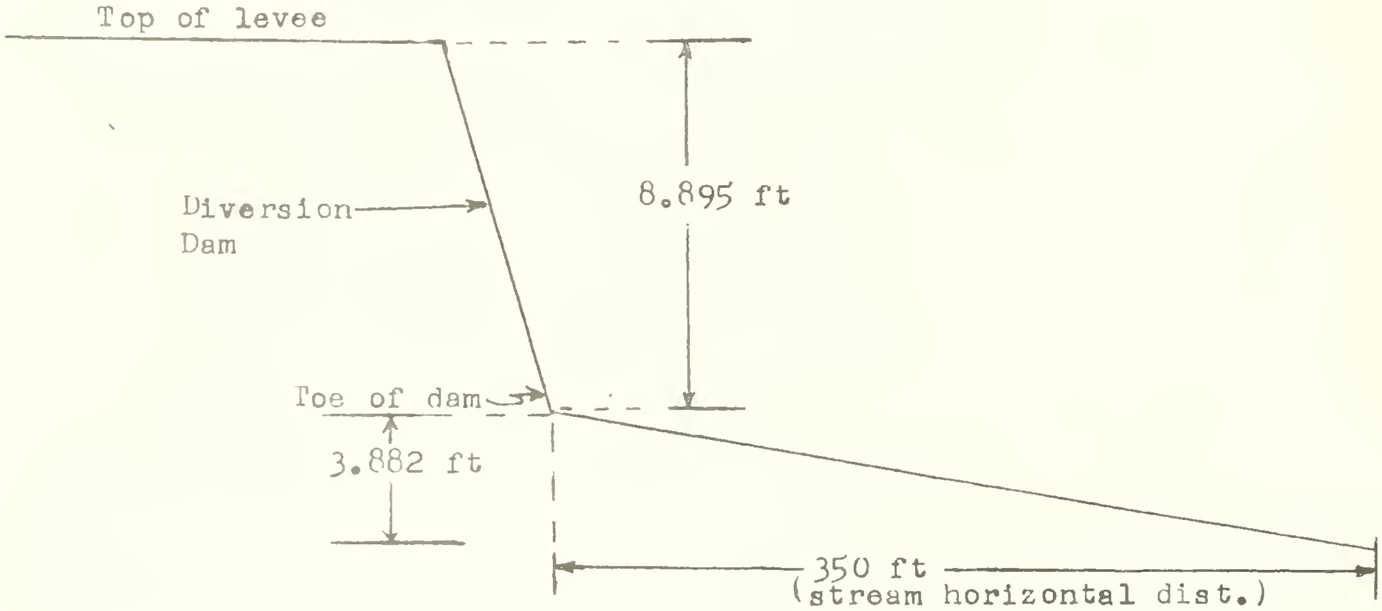
Average CFM is therefore: 1,186.6539

As the calculations require CFS, the average CFM is divided by 60

The flow measured 21 September, 1981, at a point just below the diversion dam, after extraction of city water, was 19.777CFS

Elevation measurements

A "Keuffel & Esser" precision surveying transit, calibrated rule, & steel measuring tape were used for all measurements. The slope of the creek was measured for 350 feet below the diversion dam, as well as the drop from the levee top to dam toe.



Elevation summary: Maximum head at diversion dam 8.895 feet
Slope of stream is uniform @ 0.0110914ft head per foot of horizontal flow, or 1.11 ft/100 ft distance.

The current facility was designed and constructed as a diversion dam to provide a source of city water. It was not designed to be utilized as a hydroelectric facility. To be utilized as both a water diversion and a hydroelectric generating site, either a new dam would be required or extensive modifications to the existing dam. For this reason, the top of the existing levee was used as a reference in determining the head.

POWER CALCULATIONS

The formula used to determine power is:

$$\text{Power in kilowatts} = \frac{\text{Cubic feet per second} \times \text{head in feet}}{11.8}$$

Power will be calculated on a theoretical, no loss basis. This figure will then be reduced as a function of turbine & generator efficiency, transformer & line losses.

Flow: 19.777 CFS
Head: 8.895 ft @ diversion dam
3.882 ft for 350 foot of creek run

Two applications of power will be examined at this site:
(1) Power generated by the dam site, &
(2) Power generated by the run of the stream.

(1) Power generated by the dam site

$$\frac{19.777 \text{ CFS} \times 8.895 \text{ ft head}}{11.8} = \text{Power in KW}$$

$$= 14.908 \text{ KW "No loss"}$$

The theoretical, no loss power at the diversion dam is then 14.908 KWs. This power is reduced as follows.

14.908 KW
* x 0.8 turbine efficiency
* x 0.85 generator efficiency
* x 0.95 transformer & line efficiency
9.63 KW useable power

* The efficiency numbers are conservative. Somewhat higher efficiencies are practical, but the equipment costs will be significantly higher. A practical useable number would then be 10 KW generating capacity.

Summary of power generating capability of the diversion dam.

The flow measured 21 September is representative of a reasonable flow, assuming flood control. It is therefore possible to assume the site is capable of producing a constant 10 kilowatts of useable electricity. It must be pointed out, however, that this is strictly a mathematical indication. It does not reflect the real life constraints, to be discussed shortly.

(2) Power generated by the run of the stream.

$$\frac{19.777\text{ CFS} \times 3.882\text{ ft head}}{11.8} = \text{Power in KW}$$

$$= 6.5\text{ KW "No loss"}$$

6.5 KW
x 0.8 turbine efficiency
x 0.85 generator efficiency
x 0.95 transformer & line losses
4.2 KW useable power

4.2 KW over 350 ft creek run equals 1.2 Kilowatts useable power for each 100 feet of creek, excluding penstock losses.

The land below the diversion dam was surveyed to determine slope. The slope is uniform and shallow. It is obviously too shallow to generate any practical amounts of electrical power. This survey and calculation was performed to illustrate the fact that Bozeman Creek does not have the practical potential for hydroelectric power generation without construction of a dam. There are cases where a simple pipe placed in the stream, behind a small water impoundment, can be used to run a turbine and generator. It can not be done in this area. The run of the stream will not be pursued beyond this point.

Design & costing of the diversion dam site

For the September flow a 48 inch diameter penstock would be required. Due to the low head, any smooth material capable of withstanding the environment would be satisfactory.

The primary power line from the utility company is located approximately 1 mile away. Cost is estimated to be $11,000 to bring in the power to the site.

Cost to develop the diversion dam into a site capable of producing 10 KWs of electrical power and hooked into the grid for sale to the utility company.

Bring in the utility power	$11,000.
Generator, turbine package	10,000.
Reconstruct dam	10,000.
Trash rack	300.
Water flow control gate	500.
Penstock	500.
Power house	2,500.
Switching & safety controls to match generator to utility grid	10,000.
Land fill, rip-rap	2,000.
Lighting arrestor	100.
Transformer	500.
Cost summary	$47,400.

For planning purposes, assume $47,400.00, in 1981 dollars, will be required to construct the facility.

Annual income & return on cost

10 KWs x 24 hours x 365 days will produce 87,600 KWH a year.

It must be pointed out, that while the Federal Government now requires the utilities to buy electricity generated in this manner, the law does not define how much money they must pay. The price is now being debated at hearings before the Montana Public Service Commission. It is apparent the City, or any other customer being served by the utility will receive less to sell electrical power than the dollar figure charged for consumption. The table below will indicate the annual income the City of Bozeman can expect as a function of the price per kilowatt hour paid the City by the utility company. The right hand column indicates the number of years required to recover the estimated cost of $47,400. Not knowing the source of funds to construct the facility, or the interest required, this payback period is an over simplified cost divided by annual income. The left hand column is the amount of potential income the City could be paid when selling the electricity the site generates. The prices range from approximately what the utility now charges customers to that which some individuals are now being paid or offered in the State.

[illegible]

Price City would receive per KWH	Annual income	Number of years to recover cost
3¼ ¢	$2,847.	16.65 years
3 ¢	$2,628.	18.03
* 2½ ¢	$2,190.	21.64
* 2 ¢	$1,752.	27.05
1½ ¢	$1,314.	36.07
1.1 ¢	$963.6	49.19
½ ¢	$438.	108.21
1/10 ¢	$87.6	541.09 years

*Best estimate of eventual price you would be paid.

SUMMARY Site # 1. The Diversion dam at the mouth of Bozeman Canyon.

The site is technically capable of being developed to produce marketable amounts of electrical power for sale to the utility company. To develop the site either a new dam would have to be designed and constructed, or extensive modifications made to the existing dam. It is most likely that a new dam would be required. The levee currently in place would have to be raised several feet, and the base expanded. There is no levee on the other side of the dam at this time. Another one would have to be constructed. In order to produce the indicated power, the water level would have to be raised to the top of the existing levee. The history of Bozeman Creek is one of frequent flooding. Any flooding would breach the dam & levee. The powerhouse would be destroyed by flooding. Additionally, the collection pond for city water, adjacent to the diversion dam would be flooded, contaminating the water. The site is designed to divert water for municipal use only. Until, or unless a positive means of flood control is available, to accurately control the flow of water, the site is not feasible for development. A facility designed to produce the 10 KWs of power in the fall would flood every spring without flood control. Conversely, a site designed to generate at the average high water flow, will not function correctly during low water. This site should be designed for a constant flow of water. That requirement would require a positive water control. As this study was restricted to sites at and below the diversion dam, the specifics of the headwaters of Bozeman Creek were not examined. If the city desires to dam up Bozeman Creek to combine flood control with electrical power generation, then a feasibility study of the drainage area behind the diversion dam should be considered.

The site is estimated to cost $47,400 to develop. The income probable each year will range from $1,752 to $2,190. The simple interest on $47,400 is $4,740 at 10%, $7,170 at 15%. It is unlikely the site would return even a fraction of the interest required each year.

While the site can be designed and developed to produce marketable electricity, it is not feasible without positive flood control. Even if flood control were not a concern, the site is not cost-effective, as it will not even pay the interest required on the principle costs.

It is concluded, therefore, this site is not feasible & is not likely to become feasible in the future. An additional consideration is the fact this site is located in a locked watershed. It is not a convenient area to demonstrate renewable energy sources to the public.

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The diversion dam at the mouth of Bozeman Canyon, and the surrounding area is not suitable for development as a hydroelectric facility.

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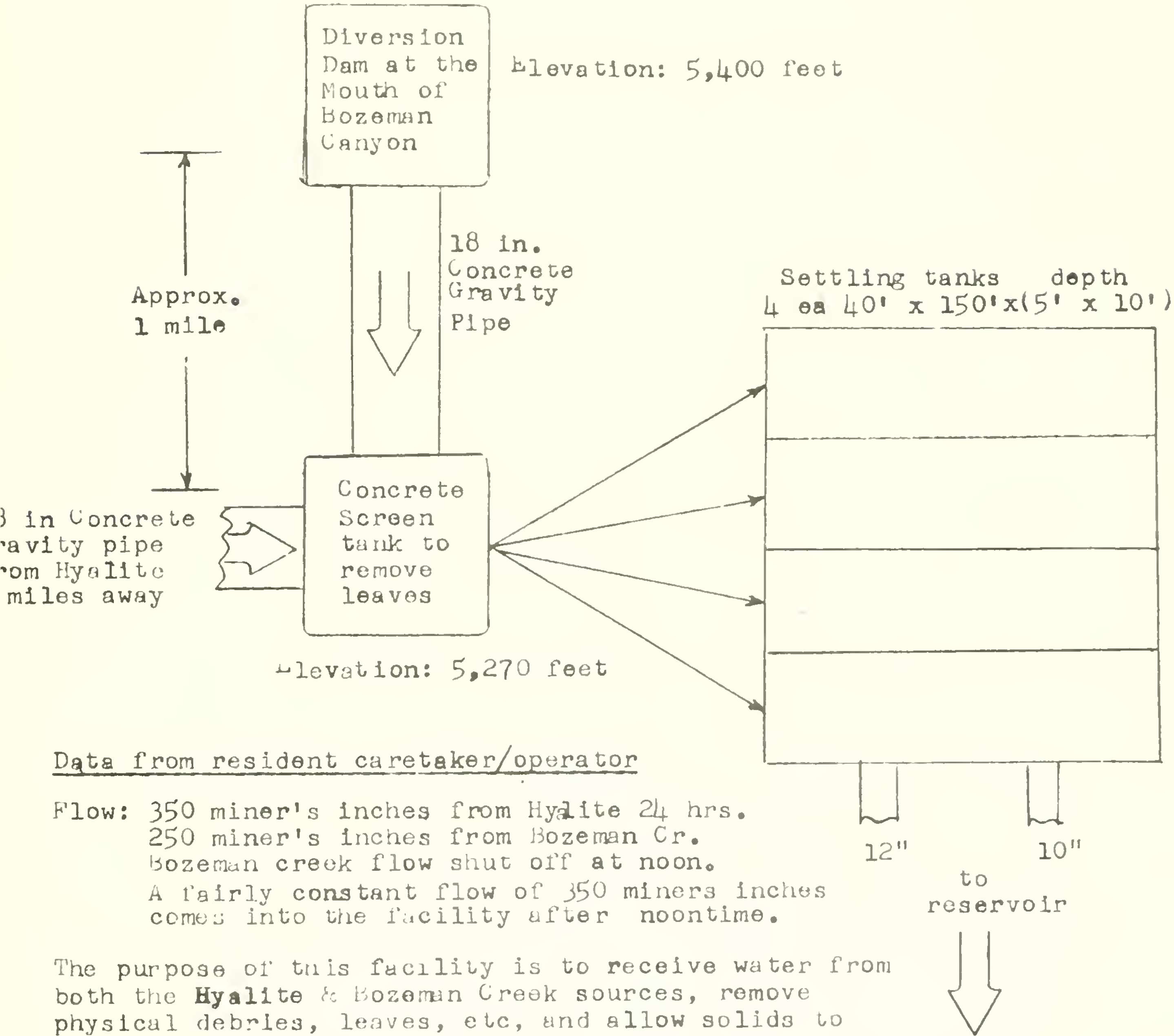
End of site study #1.

Site # 2. The presedimentation settling basins

SPECIFIC DATA GATHERED



Data from resident caretaker/operator

Flow: 350 miner's inches from Hyalite 24 hrs.
250 miner's inches from Bozeman Cr.
Bozeman creek flow shut off at noon.
A fairly constant flow of 350 miners inches comes into the facility after noontime.

The purpose of this facility is to receive water from both the **Hyalite** & Bozeman Creek sources, remove physical debries, leaves, etc, and allow solids to settle out. Physically clean water leaves, and is piped to the reservoir.

Flow data

By definition: 40 miner's inches equals 1 CFS

350 Miner's inches from Hyalite ÷ 40 = 8.75 CFS
250 Miner's inches from Bozeman ÷ 40 = 6.25 CFS

Hyalite produces 8.75 CFS on an apparent constant basis
Bozeman Creek produces 6.26 CFS on a part time basis.
Bozeman Creek is turned on & off by driving 1 mile from the presedimentation settling basins, into the locked water shed, and shutting off the flow at the diversion dam. This is apparently done on both a seasonal & diurnal basis to insure adequate water supply to the reservoir, based on consumption.

During the winter Hyalite is reduced to 200 Miner's inches, or 5.0 CFS.

The flow of water to this site varies essentially as the average consumption of city water varies throughout the year. The flow from Bozeman Creek varies from zero, after noon time, to 6.25 CFS. during morning hours. The 8.75 CFS from Hyalite, plus 6.25 CFS, makes 15 CFS available during the morning hours of summer. While input flow varies, output is constant at 6.25CFS.

Flow summary:	Summer	Winter
Hyalite	8.75 CFS	5.0 CFS
Bozeman	6.25 CFS	6.25 CFS *
	15.0 CFS until noon	11.25 CFS Assumed * Maximum
	8.75 CFS thereafter	

To analyze Bozeman Creek 6.25 CFS, on a part time basis, is the **flow.**

* The winter flow & time of shut off is not available, for this site. An analysis of the water flowing into the reservoir would indicate 6.25 CFS into the reservoir from both Hyalite & Bozeman. It is therefore reasonable to assume 6.25 CFS average flow into the settling basins during winter.

Elevation data

Elevation at the diversion dam: 5,400 feet
Elevation at the settling basins: 5,270 feet

Available head is therefore: 130 feet.

POWER CALCULATIONS

The formula used to determine power is:

$$\text{Power in kilowatts} = \frac{\text{Cubic feet per second} \times \text{head in feet}}{11.8}$$

Flow: 6.25 CFS
Head: 130 feet
Penstock Distance: 5,280 feet

The normal method of analysis to determine the net available electrical power, is to reduce the available head, as a direct function of frictional losses through the penstock, and then proceed with the power calculations. At the edge of the pipe, the water flow is turbulent, due to the friction between the edge of the pipe and the flowing water. In the center of the pipe, the flow is more smooth, or laminar. On a mile long, existing, concrete, gravity pipe, there is no practical way to mathematically construct the frictional losses to accurately express the loss of head due to the pipe. Engineering experience and judgement dictates the only conclusion possible in this case. Neither of the existing 18 inch concrete pipes from the Hyalite or Bozeman reservoirs are capable of being used as a penstock for hydroelectric power generation. They are too rough an interior surface, of insufficient diameter, and would not withstand the pressure to which they would be subjected. Additionally, as they were designed for gravity water flow, there are no pressure reliefs built in. A long pipe, high head will be subjected to both positive & negative pressures, which tend to burst or collapse the pipe without equalizing systems designed into it.

The first conclusion for this site, is the fact the existing pipe, while suitable for water supply, is not suitable for use in generating electricity. A new pipe would be required. There are no clear choices in selecting a mile long pipe. One that would withstand the operating pressures, have the required smoothness, and be of sufficient diameter so as not to reduce the available head does not exist. It would have to be designed and specially fabricated. For purposes of a feasibility study, common pipe will be considered for use. A 1.7671458 square foot entry pipe diameter will be required to approximate the existing pipe. A combination of 12 and 15 inch standard diameter pipes will be used for the purposes of costing and approximating during this feasibility study. Should the City decide to pursue this site, one of the major tasks would be the cost-effective design of the penstock. Assume a head loss of 30 feet will result from the penstock design. The power is calculated as follows:

$$\frac{6.25 \text{ CFS} \times (130-30) \text{ head}}{11.8} = \text{Power in KW}$$
$$= 52.966 \text{ KW "No loss"}$$

The theoretical, no loss power is then 52.966 KW. This power is then reduced as follows.

52.966 KW
* x 0.8 turbine efficiency
* x 0.85 generator efficiency
* x 0.95 transformer & line losses
34.216 KW useable power

* These efficiency numbers are conservative. Somewhat higher efficiencies are practical, at higher equipment costs. A practical planning number for useable generating capacity would then be 35 KW.

Summary of power generating capability

When water is flowing from the diversion dam at the mouth of Bozeman Canyon to the presedimentation settling basins, a mile away, 35 KWs of useable electrical power will be available. When the water is shut off, currently at noon time, no electrical power will be available. This power is based on the assumption an acceptable 1 mile long penstock pipe can be both designed and fabricated.

Design & costing of the presedimentation settling basins site

Primary utility power is already available in the area.

2 sets, 1,280 ft of SDR 30/30 gravity sewer pipe @ $10.30'	$26,368.
1 set, 2,000 ft SDR-41 gravity sewer pipe @ $6. ft-10"	12,000.
1 set, 2,000 ft SDR-41 gravity sewer pipe @ $10 ft-15"	20,000.
1 set, 2,000 ft PVC-200 psi pressure pipe @ $18 ft-12"	36,000.
1 set, 2,000 ft PVC-200 psi pressure pipe @ $30 ft-15"	60,000.
Pipe material costs------------------------------------	$154,368.
Generator, turbine package	35,000.
Hook up utility power	1,000.
Switching & safety controls to hook up & match generator to utility power grid	10,000.
Lightening attestor	100.
Trash rack	300.
Transformer	500.
Waterflow control gate	500.
Powerhouse	5,000.
Cost summary	$206,768.

For planning purposes, assume $206,768.00, in 1981 dollars would be required to construct the facility, excluding the labor involved to lay the pipe. There is no way to estimate the labor costs on a yet to be designed pipeline.

Annual income & return on cost

Case A will assume an average of 8 hours each day of generating capacity. Case B will assume 24 hours a day generating capacity, requiring a change in existing water use & source.

Case A: 8 hours each day, assumed to be an average day in the use of water from Bozeman Creek

35 KWs x 8 hours x 365 days will produce 102,200 KWH a year.

Case B: 24 hours each day. This case is considered, as it is not known if the water is arbitarily shut off each noon at Bozeman **Creek** in lieu of Hyalite. If it were possible to maintain water flow from Bozeman Creek & regulate from Hyalite, Case B could be **a reality**.

35 KWs x 24 hours x 365 days will produce 306,600 KWH a year.

As in Site # 1, the amount of money the City would be paid is unknown. The following table will indicate the annual income the City of Bozeman can expect as a function of the price per kilowatt hour paid the city by the utility company.

	Case A- 8 hours		Case B- 24 hours	
Price City would be paid per KWH	Annual Income	Number of years to recover cost	Annual Income	Number of years to recover cost
3¼¢	$3,577.	57.80 years	$9,964.	20.75 years
3¢	$3,066.	67.43	$9,198.	22.47
* 2½¢	$2,555.	80.92	$7,665.	26.97
* 2¢	$2,044.	101.15	$6,132.	33.71
1½¢	$1,533.	134.87	$4,599.	44.95
1.1¢	$1,124.	183.92	$3,372.	61.30
½¢	$511.	404.63	$1,533.	134.87
1/10¢	$102.	2,023.17 years	$306.	674.39 years

* Best estimate of eventual price you would be paid.

SUMMARY Site # 2. The presedimentation settling basins.

Neither of the existing concrete pipes from Hyalite or Bozeman are capable of being utilized as penstocks for a hydroelectric generating facility due to the rough interior surface, length, PSI, and insufficient diameter. It is technically possible to develop the site and produce 35 kilowatts of useable electrical power. The major problem in developing this site is the one mile distance between the site and the diversion dam in Bozeman Canyon. A special pipe would have to be designed and fabricated. The cost to design, fabricate, & install a pipe, that would work, would be prohibitively high. Even if such a pipe were feasible, the project is estimated to cost $206,768, plus the unknown cost of installing a complex mile long pipeline. Water from Bozeman creek is currently available on a part time basis only. If it were possible to modify the operating **procedures** and make water available from Bozeman creek 24 hours each day, the maximum income from the sale of electrical power would range from $6,132. to $7,665. The current operating procedure would produce an annual income from $2,044. to $2,555. The simple interest on $206,768 is $20,676, @ 10%, $31,015. @ 15%. The site is not capable of paying even a small fraction of the interest on the principle each year. The four mile distance, to the water source at Hyalite, is simply to long to be considered for hydroelectric development. Frictional losses would reduce the available head to a point where the site would not be feasible.

****

It is concluded, therefore, that this site is not feasible, on the basis that it is not cost-effective and can not be made to be so. It does not make sense to spend $206,768 to return $2,044 to $2,555 a year.

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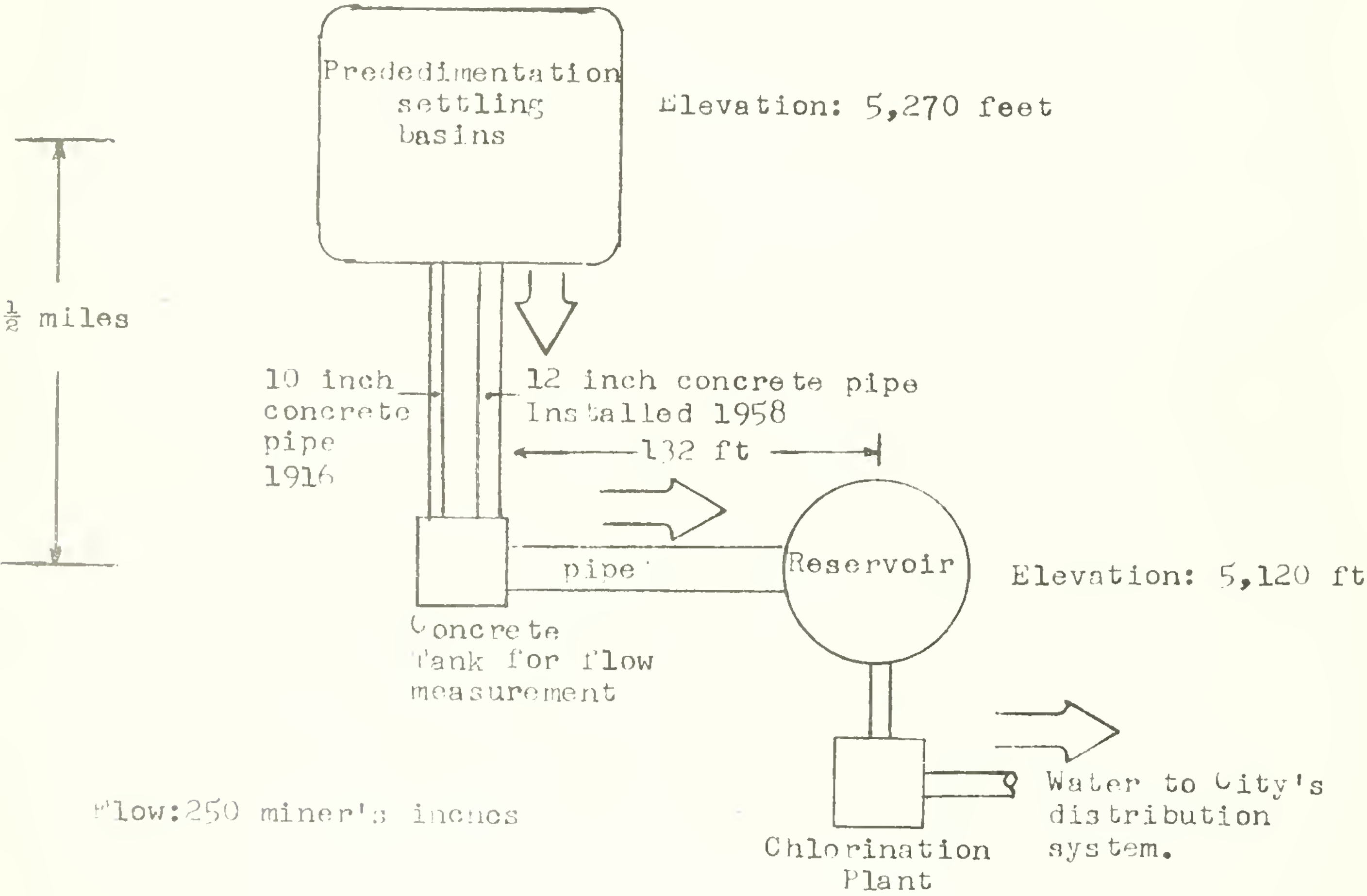
Site # 3. The municipal water reservoir.

SPECIFIC DATA GATHERED


Predeclimentation settling basins
Elevation: 5,270 feet
½ miles
10 inch concrete pipe 1916
12 inch concrete pipe Installed 1958
132 ft
pipe
Reservoir
Elevation: 5,120 ft
Concrete Tank for flow measurement
Flow:250 miner's inches
Chlorination Plant
Water to City's distribution system.

Flow data

By definition: 40 miner's inches equals 1 CFS

The resident caretaker at the presedimentation settling basins indicated the flow from his facility to the reservoir site was normally a constant 250 miner's inches. The city water department also verified the flow at 250 miner's inches. The two pipes entering the concrete measuring tank produce a a water level on a calibrated scale. The scale is calibrated to read 1 inch equals 50 miner's inches. The scale indicated 5 inches, or 250 miner's inches. The three sources produced identical flow.

250 Miner's inches divided by 40 equals 6.25 CFS
The flow is then 6.25 CFS

Elevation data

Elevation at the presedimentation settling basins: 5,270 feet
Elevation at the city reservoir------------------ 5,120 feet
Head is therefore: 150 feet.

POWER CALCULATIONS

The formula used to determine power is:

$$\text{Power in kilowatts} = \frac{\text{Cubic feet per second} \times \text{head in feet}}{11.8}$$

Flow: 6.25 CFS
Head: 150 feet
Penstock distance: $2\frac{1}{2}$ miles (13,200 ft)

The reader is referred to the long paragraph at the top of page 11. It applies to this case as well. A $2\frac{1}{2}$ mile long penstock, consisting of a 10 inch concrete gravity pipe installed in 1916, and a 12 concrete gravity pipe installed in 1958 will not function as a penstock for hydroelectric power generation. A new pipe would be required. With only a 150 foot head and $2\frac{1}{2}$ miles distance,a major engineering problems exists. The pipe would require a very smooth interior surface to reduce water flow friction. With pressure fluxuations, the lower portion would require a high pressure construction. The diameter would have to be large enough to allow flow, inconjunction with the smoothness, so as not to reduce the head to an unuseable level. While these are solveable technical problems, the cost would become excessive. As will be shown subsequently, the cost to develop this site, exclusive of the pipe problem, is to high to consider the site cost-effective.
too

For purposes of this feasibility study, it will be assumed that a pipe can be designed. Further assume a head loss of 45 feet would result.

The power is then calculated as follows:

$$\frac{6.25 \text{ CFS} \times (150-45) \text{ head}}{11.8} = \text{Power in KW}$$

$$= 55.61 \text{ KW "No loss"}$$

The theoretical, no loss power, is then 55.61 KW. This power is reduced as follows:

55.61 KW
* x 0.8 Turbine efficiency
* x 0.85 Generator efficiency
* x 0.95 Transformer & line losses
35.92 KW useable power

* These efficiency numbers are conservative. Somewhat higher efficiencies are practical, at higher equipment costs.

For planning purposes, assume 36 KWs of useable power could be generated, assuming the penstock pipe problem could be solved.

Summary of power generating capability.

36 kilowatts of useable power can be generated at the reservoir site on a constant basis. This assumes the unlikely possibility of an acceptable 2½ mile long penstock pipe being available.

Design & costing the municipal water reservoir site.

Utility primary power is already available in the area.

The pipe will be costed, for purposes of this study, on the basis of commerically available pipe, used in parallel.

2 sets, 4,200 ft SDR 30/30 gravity sewer pipe @ $10.30'	$86,520.
1 set, 4,500 ft SDR-41 gravity sewer pipe @ $6 ft 12"	$27,000.
1 set, 4,500 ft SDR-41 gravity sewer pipe @ $10 ft 15"	$45,000.
1 set, 4,500 ft PVC-200 psi pressure pipe @ $18 ft 12"	$81,000.
1 set, 4,500 ft PVC-200 psi pressure pipe @ $30 ft 15"	$135,000.
Penstock material costs-------------------------------	$374,520.
Generator, turbine package	36,000.
Hook up utility power	$1,000.
Switching & safety controls to hook up & match generator to utility power grid	$10,000.
Lightening arestor	$100.
Powerhouse	$7,500.
Water flow control gate	$500.
Cost summary	$429,620.

For planning purposes, assume $429,620, in 1981 dollars, would be required to construct the facility, excluding the engineering and labor required to design, fabricate, & install the 2½ mile long pipeline. The material costs shown for the pipe would be in the cost "ballpark."

Annual income & return on cost

36 KWs x 24 hours x 365 days will produce 315,360 KWH a year.

As in prior sites, the amount of money the utility company will pay the City is unknown. The following table will indicate the annual income the City of Bozeman could expect as a function of the price per kilowatt hour paid.

Price the City would receive per KWH	Annual income	Number of years to recover cost
3¼¢	$10,249.	41.91 years
3¢	$9,460.	45.41
* 2½¢	$7,884.	54.49
* 2¢	$6,307.	68.11
1½¢	$4,730.	90.82
1.1¢	$3,468.	123.84
½¢	$1,576.	272.46
1/10¢	$315.	1,362.31 years

* Best estimate of the eventual price you would be paid.

SUMMARY Site # 3. The municipal water reservoir.

Neither of the two existing pipes from the presedimentation settling basins to the reservoir can be used as a penstock for a hydroelectric generating facility. 2½ miles is simply too long a distance. The pipe is too rough internally, of insufficient diameter, would not take the pressure, and one of the pipes, installed in 1916, would probably fail. A new pipe would be required. It is a technical possibility to design and construct the facility. If it were constructed, 36 KWs of useable power could be produced. It would be a major engineering challenge to design a 2½ mile long pipeline that would work, without requiring a prohibitively high cost. Even if the pipe line problem could be solved, the project is estimated to cost $429,620, plus the cost of installing the pipe. This cost would return between $6,307 & $7,884, each year. The simple interest on the $429,620 cost is $42,960 a year @ 10%, $64,443, @ 15%. This site is not capable of returning even a 2% annual yield.

****

It is concluded, therefore, that the municipal water reservoir is not feasible to be developed as a site for hydroelectric power generation. It would cost at least $429,620 to develop, produce only $7,884 annual income. It is obviously not cost-effective. Additionally, 2½ miles is too long a distance to design & construct a penstock pipeline.

****

Site # 4. Down town Bozeman adjacent to the new library.

SPECIFIC DATA GATHERED

Flow measurements

Four different sites downtown were measured, & then averaged.

Case # 1. Width of the waterway: 14 ft, 9 in. 14.75 ft
Depth measurements: (all figures are in inches)
8½,8½,9 3/4,10 3/4,11 3/4,11½,12,12½,12,10 3/4,13,12½,11 3/4,
10½,9,9,9 Average: 10.75 " 0.89583 ft

Case # 2. Width of the waterway: 14 ft, 9 in. 14.75 ft
7½,10,10,13,11 3/4,12,11½,11,13 3/4,15,12,12½,13,10,7,9,9
Average: 11.058" 0.92156 ft

Case # 3. Width of the waterway: 14 ft, 9 in. 14.75 ft
8½,8,7,10½,10¼,11,12,14,14,13 3/4,13½,13,11½,10½,10½,12,11,
9½,10,10 Average: 11.025" 0.91875 ft

Water velocity measurements

Float distance measured was 70 feet.
Float times:(all figures are in seconds)
28,25,22,22,21,24,23,21 Average: 23.25 seconds

Flow calculations

The following formula was used to calculate flow:
The width of the stream, in feet, times the depth, in feet, times the distance the float travels in one minute, times the constant, 0.8, equals the cubic feet per minute of flow.

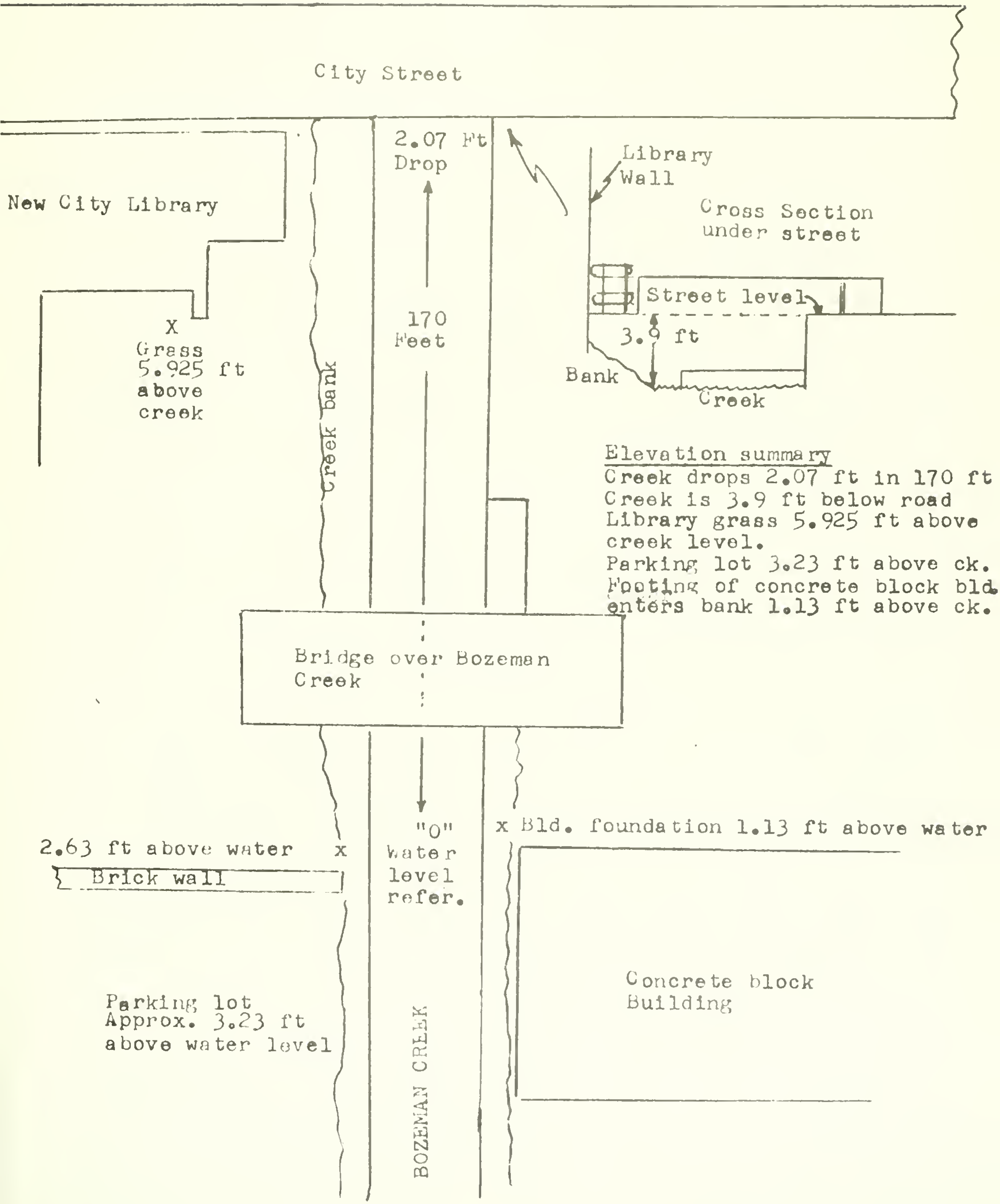
The three cases measured, are computed & averaged as follows:

Case	Water depth	x Width	x Distance trav. in 1 M	x K	= CFM
1	0.89583	x 14.75	x (60 ÷ 23.25 x 70)	x0.8	= 1,909.5626
2	0.92156	x 14.75	x (60 ÷ 23.25 x 70)	x0.8	= 1,964.4089
3	0.91875	x 14.75	x (60 ÷ 23.25 x 70)	x0.8	= 1,958.4191
			Average CFM		1,944.1271

As the calculations require CFS, CFM is divided by 60.
The average flow downtown is therefore: 32.402 CFS

Elevation measurements

A "Keuffel & Esser" precision surveying transit, calibrated rule, & steel measuring tape were used for all measurements. The creek and lands surrounding the new City library were surveyed. The results are shown on the next page.



Elevation summary
Creek drops 2.07 ft in 170 ft
Creek is 3.9 ft below road
Library grass 5.925 ft above
creek level.
Parking lot 3.23 ft above ck.
Footing of concrete block bld.
enters bank 1.13 ft above ck.

POWER CALCULATIONS

The formula used to determine power is:

$$\text{Power in kilowatts} = \frac{\text{Cubic feet per second} \times \text{head in feet}}{11.8}$$

Power will be calculated on a theoretical, no loss basis. This figure will then be reduced as a function of turbine & generator efficiency, transformer & line losses.

Flow: 32.402 CFS
Head: 2.07 feet

$$\frac{32.402 \text{ CFS} \times 2.07 \text{ ft head}}{11.8} = \text{Power in KW}$$

$$= 5.684 \text{ KW "No loss"}$$

The theoretical, no loss power, at the library site, is 5.684 KW This power is reduced as follows.

5.684 KW
* x 0.8 Turbine efficiency
* x 0.85 Generator efficiency
* x 0.95 Transformer & line efficiency
3.67 KW useable power

* These efficiency numbers are conservative. Somewhat higher efficiencies are practical. The library site is theoretically capable of producing 3.67 KW

Summary of power generating capability of the library site.

It is theoretically possible to generate 3.67 KW of useable power at this site. The word theoretically is used, as the slope of the land is too shallow to allow a dam to be constructed. It is possible to construct a concrete channel from the the next street upstream to the area of the library. This would contain the water behind the small dam. However, an absolute flood control system, which does not exist, would be required. Such a channel would be most unsitely for a beautiful area. Another problem is the fact that the creek drops only 2.07 feet in 170 feet. The turbine and generator vertical dimensions are very close to that. Unless provisions were made to install the generating equipment underwater, the available head is lost, and no power could be generated.

Costing the system

The major cost associated with the library site, is constructing a concrete "U" shaped water way from the street upstream to a point just downstream from the bridge. This would have to be of sufficient height to prevent water from overflowing .

Concrete waterway & dam structures estimated @ $30,000.

Construction of waterway & dam	$30,000.
Flow gate control valve	1,000.
Generator & turbine package	8,500.
Power house	2,500.
Switching & safety controls to match generator to utility grid	7,500.
Transformer	500.
Trash rack	300.
Lighting arrestor	100.
Total estimated cost	$50,400.

Annual income & return on cost

3.67 KWs x 24 hours x 365 days will produce 32,149 KWH a year.

As in each prior site, the price the City would be paid for the power is unknown. The following table will indicate the annual income and the payback period.

Price City would receive per KWH	Annual income	Number of years to recover costs
3½¢	$1,125.	44.8 years
3¢	$964.	52.25
* 2½¢	$804	62.7
* 2¢	$643.	78.38
1½¢	$482.	104.51
1.1¢	$354.	142.51
½¢	$161.	313.54
1/10¢	$32.	1,567.70 years

* Best estimate o eventual price the city would be paid.

SUMMARY Site # 4. Down town Bozeman, adjacent to the new library

The site is theoretically capable of producing 3.67 Kilowatts of useable electrical power. Due to the very shallow slope of the land through the entire down town area it would not be practical to construct a dam on Bozeman Creek. The creek only drops 2.07 feet over 170 feet horizontal distance. This is typical in the City limits. Bozeman Creek is subject to periodic and uncontrolled flooding. To attempt damning the creek, would require both rasing the water level behind the dam, and constructing an unsightly & expensive concrete channel. The resulting water level would be at or above existing buildings & other improvements. Each spring the facility would flood the area. Additionally, there is no practical means of mounting the turbine below the head of water. Whenever the periodic flooding occurs, it is most likely the library would be subjected to excessive water damage if a da were built at the site. While the volume of water is sufficient at the site, the entire area is simply to shallow to make a hydroelectric generating site feasible. Even if it were possible to devise solutions to these problems, the site would not be cost-effective. The site is estimated to cost $50,400 to construct. It could return between $804 & $643 annually. Interest on the $50,400 cost would be $5,040 @ 10%, $7,560 @ 15%.

The site is not capable of generating a portion of the interest on the cost large enough to be considered feasible.

There is one possibility, however. An undershot water wheel, with a mechanism to position the wheel as a function of water level, could be installed. The wheel could be used to power a small generator for such things as Christmas tree lighting, or some outdoor lighting. It would be aesthetically more acceptable than a concrete channel & dam. Water wheels are not very efficient and, in this case, would be capable of using only a small portion of the creek's energy. This is the only practical means of generating electrical power at the library site.

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The library site, down town Bozeman, is not feasible for development as a hydroelectric generating site. There is insufficient drop in the creek, the area is a flood plane, any damming of the creek in the area would result in excessive flood damage each spring, and the cost is excessive, $50,400, compared to the expected return of between $643 to $804 annually. Bozeman Creek is subject to periodic & uncontrolled flooding. Extensive flood damage, in addition to the yearly spring floods, would result if a dam were built at the site. The only possible use of the site, for demonstration purposes, would be the installation of an undershot water wheel to power small lighting.

****

Site # 5. From the railroad trestle over Bozeman Creek, along the railroad right of way, to the City park.

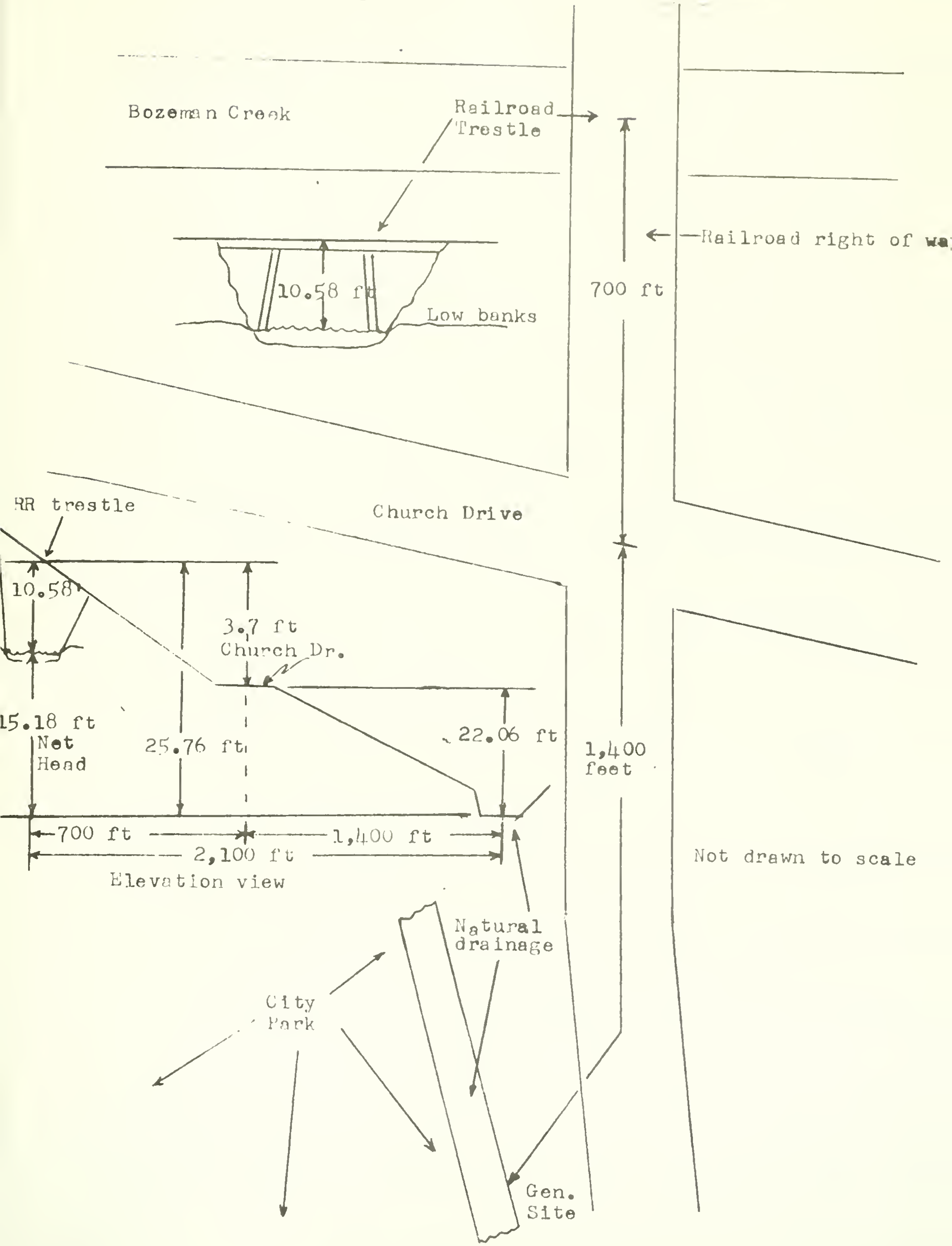
Specific data gathered

Flow measurements

The flow measurements were taken at the library site, and will be used for this site. Flow is 32.402 CFS

Elevation measurements

A "Keuffel & Esser" precision surveying transit, calibrated rule, & steel measuring tape were used for all measurements. Surveying was started at the water level under the railroad trestle. The entire railroad right of way was surveyed down to a potential generating site at the City park. The measurements are shown on the next page.


Bozeman Creek
Railroad
Trestle
10.58 ft
Low banks
Railroad right of wa
700 ft
Church Drive
RR trestle
10.58'
3.7 ft
Church Dr.
15.18 ft
Net
Head
25.76 ft
22.06 ft
1,400
feet
700 ft
1,400 ft
2,100 ft
Elevation view
Not drawn to scale
Natural
drainage
City
Park
Gen.
Site

Elevation summary

A horizontal distance of 2,100 feet runs from the railroad trestle above Bozeman Creek to a potential generating site in the natural drainage adjacent to the City Park. The water level in Bozeman Creek is 10.58 feet below the top of the trestle level. The slope of the railroad bed is uniform over its length, at approximately 0.52857 foot drop per 100 foot of horizontal distance. The net head is 15.18 feet. The penstock pipe would be 2,100 feet long.

The area surveyed is an existing railroad bed. It has not been used for some time. Its ownership &/or right to its use is unknown.

POWER CALCULATIONS

The formula used to determine power is:

$$\text{Power in kilowatts} = \frac{\text{Cubic feet per second x head in feet}}{11.8}$$

Power will be calculated on a theoretical, no loss basis. This figure will then be reduced as a function of turbine & generator efficiency, transformer & line losses.

Flow: 32.402 CFS
Head: 15.18 feet
Penstock distance: 2,100 feet

$$\frac{\text{32.402 CFS x 15.18 ft head}}{11.8} = \text{41.68 KW "no loss"}$$

The theoretical, no loss power, is then 41.68 KWs. This power is reduced as follows.

41.68 KW
* 0.8 turbine efficiency
* 0.85 generator efficiency
* 0.95 transformer & line efficiency
26.92 KW useable power

* The efficiency numbers are conservative. Somewhat higher efficiencies are possible, but the equipment costs would be significantly higher. A practical useable number would be 27 Kilowatts of useable power from this site.

Summary of power generating capability of the railroad site.

The flow measured 21 September at the library site is typical of the flow at the railroad site, assuming some means of flood control. Neglecting the frictional losses of the 2,100 foot long penstock pipe, 27 kilowatts of useable power could be developed. This site has several very fundamental problems, however, that makes it unfeasible to consider this a viable generating facility. First, the slope of the land, in the area of the railroad trestle, is too shallow to enable a dam to be constructed. Second, the railroad trestle is 10.58 feet above the water level. Either a pump would be required to raise the level of the water up to the railroad bed, (a siphon system is not feasible here) or the the railroad bed would have to be dug up to install a pipe line, thereby destroying the tracks & the bed. Third, all the water flowing in Bozeman Creek would have to be diverted to generate the indicated electrical power. Fourth, the City does not own the water rights to Bozeman Creek along the entire potential vacated water way. The cost of aquisition would be prohibitive, both in time, money & adverse public opinion. Last, & of great importance, if Bozeman Creek were to be rerouted to the natural drainage area next to the City park, the entire developed area down stream of the park would be flooded, as the channel is not capable of handling the volume of water. Of unknown effect is ownership and use of the right of way of the railroad bed. It apparently does not currently belong to the city.

Discounting the above reasons, one of the more difficult problems remain, that of obtaining a cost-effective 2,100 foot long pipe line. With only 15.18 foot drop over a 2,100 foot distance, the water must flow with little friction. There is no "stock" pipe available. One would have to be designed & fabricated. A pipe of slightly over 4 foot diameter would be required. For purposes of costing this site, several standard pipes will be used. It would be a major engineering challange to obtain a penstock for a reasonable cost that would do the job.

Design & costing of the railroad site

Penstock pipe costs (estimated)	$214,200	to $315,000.
Generator, turbine package		$27,000.
Lift pump & electricl hookup		$10,000.
Power house		$3,500.
Switching & controls to match generator to utility grid		$10,000.
Transformer		$500.
Lighting arrestor		$100.
Diversion dam, levees, rip-rap		$15,000.
Water control valve		$500.
Cost summary	$280,800	to $381,600.

For planning purposes, assume the project to cost between $280,800 and $381,600, in 1981 dollars, depending on the pipe line eventual costs. This estimate does not include the cost of installing the pipeline.

Annual income return on cost

27 KWs x 24 hours x 365 days will produce 236,520 KWH a year. As in each of the prior sites, there is no way to determine how much money the utility company will pay the City for the power generated. The following table will indicate the annual income, & payback period, as a function of the price paid.

Price City would receive per KWH	Annual income	Number of years to recover cost
3½¢	$8,278.	46.09 years
3¢	$7,095.	53.77
* 2½¢	$5,913.	64.53
* 2¢	$4,730.	80.66
1½¢	$3,547.	107.55
1.1¢	$2,601.	146.67
½¢	$1,182.	322.67
1/10¢	$236.	1,613.39 years

* Best estimate of eventual price you would be paid.

SUMMARY: From the railroad trestle, over Bozeman Creek, along the railroad right of way, to the City park.

The site is theoretically capable of generating 27 Kilowatts of useable electrical power. However, from both a practical and a cost-effective standpoint, the site is not feasible for any one of the following reasons.

1. The slope of the land in the vicinity of the trestle is too shallow to construct a dam to impound the water.
2. The water would have to be pumped uphill 10.58 feet to the top of the railroad right of way.
3. All the water in Bozeman Creek would have to be diverted from the existing creek bed to generate the indicated power. The City does not currently own all the required water rights. The cost to obtain the necessary water rights is unknown, but estimated to be prohibitive. It would take years to obtain these rights & would create negative public opinion.
4. To route a pipeline down the railroad would require removal of the rails and ties. The process would essentially destroy the railroad bed & facilities. The ownership &/or use of the necessary right of way(s) is unknown. The City of Bozeman apparently does not have the current rights required for its use.
5. It is highly unlikely the requsite permits could be obtained for the project.
6. The 2,100 foot penstock is not practical for a 15.18 foot drop.
7. The project is estimated to cost between $280,800 to $381,600, plus installation costs for the 2,100 foot pipeline. The interest would be $38,160, @ 10%, $57,240 @ 15% for costs each year. The annual income is estimated to be between $4,730 and $5,913. It is obviously not cost-effective.
8. If Bozeman Creek were diverted to the natural drainage,next to the City park, there is insufficient capacity to handle the volume of water. Constant flooding would result. The area is densely developed. It would be unthinkable to reroute Bozeman Creek to this area.

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The railroad right of way site is not feasible for any of the above 8 reasons.

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COLLATION OF PRIOR STUDIES

In recent times Bozeman Creek has been the subject of several water quality and flow studies. The recorded flow data is collated in the following table. Data was supplied from the following sources:

(1) Mr. Joel A Shouse, Executive Director, "Blue Ribbons of the Big Sky Country **Areawide** Planning Organization" water quality monitoring program, 35 E. Mendenhall, Suite 206, Bozeman, Montana. The flow of water was monitored at Tamarack Street, approximately ½ mile downstream from the new library during 1976-77.

(2) Mr. Claud Matney, Matney-Frantz Engineering,Energy Consultants, 849 West Main, Bozeman, Montana. Mr. Matney conducted the above measurements & interperted the flow data.

(3)Montana University Joint Water Resources Research Center, Montana State University, Bozeman, Montana. Completion Report, Project No. B-040 Mont, March 1976. Bozeman Creek was monitored for flow at the mouth of the canyon below the City's water diversion structure during 1971-72. Data was extracted from MUJWRRC report No. 74

(4) MUJWRCC report No. 93 supplied by Mr. William Hunt of the Montana Water Resources Research Center, Montana State University, Bozeman, Montana, a joint effort of MSU & Montana College of Mineral Science, Butte, Montana.

(5) Mr. Russ Heliker, Energy Planner, City of Bozeman, supplied flow data of Bozeman Creek at **Kagy Blvd. Matney-Frantz Engineering**, covering the period 1977-78

(6) Mr. William Hunt, of the Montana Water Resources Research Center, Montana State University, supplied USDA-Soil Conservation Service flow measurements of Bozeman Creek, at the Forest Service boundary, covering the period 1951-1977.

The flow data from the studies listed on the previous page is collated in the following table. All data is shown in cubic feet per minute of flow.

Month	1976 M3A Site (1)	1976 M-4 Site (2)	1976 M4-X Site (3)	76-77 APO Site (4)	71-72 M-3 Site (5)	1951 USDA (6)	1952 USDA (7)	1953 USDA (8)	1975 USDA (9)	1976 USDA (10)	1977 USDA (11)
Jan.							9	8			
Feb.							7	6			
Mar.	2	6	6	0	5		7	8			
Apl.	25	20	30	0	5		*22 *55	8			
May	120	144	155	67		68	82	22	73	*261 *290	60
June	62	117	126	*1.55 *31	16	40	49	105	300	76	58
July	10	43	49	*42 *8.7	8	32	49	61	51	29	
Aug.	7	27	38	24	8	16	24	29	45	33	24
Sept.	9	33	42		*7 *6	15	30	15	18	32	23
Oct.	13	20	35	0	7	13	12		22	33	20
Nov.	2		18	0	11	12					
Dec.	2	10				9	12				

* Two entries are shown in the report.

Following are the site locations:

(1) M3A: Approximately 5 miles from town, up Bozeman Creek, assumed to be in the vicinity of the diversion dam.
(2) M-4: Approximately 2½ miles from town at the point where Limestone Creek merges with Bozeman Creek.
(3) M4-X: Approximately 1,000 meters downstream from M-4.
(4) APO site: Tamarack Street, ¼ mile downstream from new library.
(5) M-3: Area of water diversion dam.
(6) through (11) Approximately ¼ mile above the settling basin, up Bozeman Canyon.

This feasibility study measured 32 CFS at the Library site, and 20 CFS below the diversion dam during September 1981.

Two basic conclusions can be drawn from the above data:

1. The flow varies dramatically during the year.
2. Periodic, and uncontrolled flooding occurs.

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